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The Prairie Naturalist

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Final Thoughts as Editor-in-Chief

Greetings GPNSS members! I write this editorial during a time of reflection as Editor-in-Chief of *The Prairie Naturalist (TPN)*, and during unprecedented times as the global COVID-19 pandemic continues. In full disclosure, I do not have a particular topic for this editorial, other than to offer a few final thoughts as my time serving the Great Plains Natural Science Society and *TPN*.

First, I would like to extend my sincere gratitude and appreciation to everyone who has helped me during the past 11 years. Giving the appropriate thanks to these people would take pages, and perhaps volumes, but you probably aren't interested in reading volumes. Instead, perhaps you can humor me while I give thanks to those most deserving. During my earlier years as EIC, Troy Grovenburg and Brandi Felts were warriors among us for their dedicated service as assistant and newsletter editors, who had significant roles in actually running *TPN*. They handled countless inquiries from dealing with authors and GPNSS members, handling membership renewals, getting manuscripts to production, preparation of the quarterly newsletter…you get the point. During the latter half of my tenure, my former advisor (Dr. Jonathan Jenks) assumed the role as acting assistant editor, whose efforts were instrumental during transition years for *TPN*. Without their effort, the timely publication of *TPN* surely would have been compromised. I considered their collective efforts a series of ongoing personal favors, of which I will likely never be able to properly return.

I was very fortunate to have an excellent pool of Associate Editors stay on during my transition to EIC. Since then, I had another group of Associate Editors agree to serve when I asked them, and collectively, all of these individuals did an outstanding job. I know from years of service as an Associate Editor, it is often a thankless job, and once that requires developing a "thick skin" in short order. I have tremendous respect for the Associate Editors who served during my tenure, because they are the work horses of the peer-review process and in doing so, shouldered an important task and devoted themselves to doing it well. Lastly, and before I welcome incoming Editor-in-Chief Jane Austin, I would be remiss without thanking the authors and co-authors of the hundreds of manuscripts that I handled during my tenure. You are a passionate bunch and your dedication to research throughout the Great Plains is admirable. Part of being EIC requires difficult conversations with authors, and addressing their concerns is something that I have always prioritized. From day one, I felt it important to handle author complaints and concerns professionally, and in as timely of a manner as I was able. At times, conversations often slipped through the cracks in the daily chaos of our busy schedules, and sometimes required making decisions unpopular with authors. Nevertheless, authors responded to my decisions professionally and respectfully, and for that I am forever grateful. I sincerely appreciate the opportunity to interact with all of you, and thank you for the opportunities to learn more from you than you have from me.

Finally, I want to share with you several parting thoughts during my tenure as EIC, that I now find myself reflecting on more frequently than the earlier years of service to the *TPN*. I hope that some of you devote some time self-reflecting on whether they also apply to you. First, there can be no doubt that I am a workaholic who has juggled excessive responsibility (like service to professional journals) for decades. If I run out of things to do, then I will find an excuse to create more work for myself. Like all of you, I have little spare time, and my personal and professional obligations are indeed daunting. For too many years now I have allowed my passion, or perhaps more appropriately my obsession, for work to be more of a priority than more important things in my life, such as family and friends. The drive to be successful, publish manuscripts, secure external grant funding, and mentor graduate students consumed me to the point of leaving little spare time. Regrettably, so many of us can relate to this character flaw. Rather than lament over how hectic our lives are, and how we have little time to enjoy what is really important, perhaps we all should reflect on how thankful we should be for the lives and professions we enjoy. Since my decision to transition out of my professional service to the various journals I have served for the better part of 20 years, I have given pensive thought to the things I am truly thankful for in the chaos of my day-to-day obligations. To be sure, I am thankful for my kids, because at the end of the day, they don't care how bad your day was, or how much work you need to get done. They simply want your attention, and being a positive role model in their lives will leave you a better person. Simply stated, few people will care how many papers you published, how many graduate students you mentored, or how much grant money you received during your career. Rather, your measure as a person will be assessed by your friends and family, and how you have positively affected them. Lastly, I am thankful for the many rewarding and positive experiences that I have been able to purse in my journey through the wildlife profession. Yeah, many of the pressures we face may be self-incurred, but we are still a fortunate group of professionals to be able to conduct the work we do. Take the time to appreciate the positive things in your lives, because doing so will provide perspective and relieve stress that too often affect our day-to-day lives.

In this Issue–Once again, this issue of *TPN* contains a wide range of topics that reflects the breadth of work being conducted across the Great Plains. Several articles detail natural history, disease ecology, and geographic distribution of terrestrial vertebrates across the northern Great Plains. Another article investigates factors limiting reintroduced fish populations in central Great Plains streams. This issue also includes a several book reviews, ranging from grasslands and climate change, to Great Plains birds, to birds of prey of eastern North America, to natural history and habitats of woodcock. There is a range of information available to professionals and outdoor enthusiasts across the Great Plains.

In closing, I hope you will continue to support *TPN*, incoming Editor-in-Chief Jane Austin, and the editorial staff responsible for ensuring its publication. I look forward to seeing you sometime in the future. Until that time, I wish you all continued good health to you and your families, and a safe and productive field season!

—Christopher N. Jacques
Editor-in-Chief

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Bats of the Loess Hills Ecoregion of Southeast Nebraska

VIRGIL BRACK, JR., DALE W. SPARKS, AND DARWIN C. BRACK

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ABSTRACT We surveyed bats at 49 sites in the Loess Hills Ecoregion of southeastern Nebraska, along the western edge of the eastern forest biome in eastern Richardson, Nemaha, and Otoe counties. We completed this study shortly before the northern long-eared bat (*Myotis septentrionalis*) was listed by the United States Fish and Wildlife Service under the Endangered Species Act. The expectation of listing, along with potential presence of the endangered Indiana bat (*Myotis sodalis*), motivated the study. We captured 183 bats of five species: eastern red bat (*Lasiurus borealis*) (*n* = 103; 56 %), big brown bat (*Eptesicus fuscus*) (*n* = 47; 26 %), evening bat (*Nycticeius humeralis*) (*n* = 27; 15 %), hoary bat (*Lasiurus cinereus*) (*n* = 4; 2 %), and northern long-eared bat (*n* = 2; 1 %). The mean catch per net site was 3.7 bats (*SD* = 4.8). The Eastern red bat was captured most commonly and at the most sites. We established the first record of this species from Nemaha County, with reproduction documented in all three counties. More reproductive female red bats were captured than adult males. Big brown bat captures consisted of approximately equal proportions adult males, reproductive females, and volant young of year. We established the first records for big brown bat reproduction in Otoe and Nemaha counties. Only reproductive female and juvenile evening bats were captured, with geographic and reproductive records established for all three counties. Captures of the hoary bat, a lactating female at one site and two juveniles at another, represented a Nemaha County geographic and reproductive record. We radio-tagged a non-reproductive female and an adult male northern long-eared bat from Otoe County and tracked them to roosts along the Missouri River, 3.43 and 2.03 km from the net site, respectively. We completed four emergence counts at each roost, with each bat exiting its respective roost on only one evening and neither bat visiting the other roost. We never documented more than three individuals exiting each roost on a given night. Overall, this study documented relatively low abundance, species richness, and species diversity when compared to studies in the eastern United States.

KEY WORDS bats, endangered, Nebraska, northern long-eared bat, threatened

Literature indicates that 8 of 13 species of bats known from Nebraska reside in southeastern Nebraska (Czaplewski et al. 1979, Jones et al. 1983, 1985, Benedict 2004): the northern long-eared bat (*Myotis septentrionalis*), little brown bat (*Myotis lucifugus*), silver-haired bat (*Lasionycteris noctivagans*), big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis*), hoary bat (*Lasiurus cinereus*), evening bat (*Nycticeius humeralis*), and tri-colored bat (*Perimyotis* [previously *Pipistrellus*] *subflavus*). In addition, the Brazilian free-tailed bat (*Tadarida brasiliensis*) is an uncommon visitor in Nebraska in late summer (Genoways et al. 2000). The Indiana bat (*Myotis sodalis*) is known from short distances to the east in Missouri and Iowa but is not a known resident of Nebraska. Although these eight species occur in eastern forests, information about distribution, abundance, and habitats is lacking in southeastern Nebraska (Benedict 2004). Lack of such basic information is troubling in light of the fungus *Pseudogymnoascus destructans*, the causative agent of white-nose syndrome (WNS), which is responsible for catastrophic population declines in bats that hibernate in caves throughout eastern North America (detailed at https://www.whitenosesyndrome.org/partner/us-fish-wildlife-service). On 4 May 2015, the United States Fish and Wildlife Service (USFWS) listed the northern long-eared bat as threatened under the Endangered Species Act (ESA). This study was completed shortly before the northern long-eared bat was listed by the USFWS but was motivated by the move toward listing, along with potential presence of the endangered Indiana bat.

Eastern Nebraska is at the interface of major biomes: the Dissected Till Plains held the westernmost extent of the eastern deciduous forest, while the Great Plains were characterized by treeless prairie. The eastern half of the state has a humid continental climate, while the western half has a semi-arid climate. Average annual precipitation decreases from about 800 mm in the southeast corner of the state to about 350 mm in the southwestern panhandle. Beyond obvious change in vegetation, the range of many species of animals in the eastern United States (U.S.) ends at this biome divide or their abundance is dramatically altered (Olson et al. 2001). Thus, the Loess Hills of southeastern Nebraska, at the western edge of the eastern forest biome, is an ideal place to compare bat assemblages to more "typical" wooded eastern locations. We compare our data to similar studies in eastern deciduous forests of Indiana, Ohio, Pennsylvania, Virginia, and West Virginia, and with captures in an adjacent portion of Kansas. While such a comparison is important for this reason alone, arrival of WNS has the potential of forever changing this relationship, so pre-WNS data are particularly valuable.

STUDY AREA

We captured bats in the Nebraska/Kansas Loess Hills portion of the Great Plains, Temperate Prairie, Western Corn Belt Plains Ecoregion (Chapman et al. 2001) in eastern Richardson, Nemaha, and Otoe counties in southeastern Nebraska (Fig. 1). The area is glaciated and characterized by deep, rolling loess-covered hills and perennial streams. Loess is underlain by calcareous glacial till on Pennsylvanian shale, sandstone, and limestone. The elevation is 300 - 460 m with local relief of 30 - 90 m. Annual precipitation is 66 - 86 cm, and the area has 150 - 190 frost-free days annually.

Prior to the 1860s, the study area was a transition zone between forest and prairie ecosystems (Kaul and Rolfsmeier 1993). Floodplains along the Missouri River and its tributaries were covered by riparian forests containing bur oak (*Quercus macrocarpa*), basswood (*Tilia americana*), black walnut (*Juglans nigra*), green ash (*Fraxinus pennsylvanica*), cottonwood (*Populus deltoides*), and willows (*Salix spp.*). Loess deposits were capped by oak-hickory (*Quercus-Carya*) forests, which gave way to upland prairies containing big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and little bluestem (*Schizachyrium scoparium*). Steeper slopes now support pastures and scattered trees, whereas low-relief areas are dominated by fields of corn, soybeans, small grains, and alfalfa, with few remaining prairies. Roads, towns, and utility corridors are present throughout the region. Benedict et al. (2000) addressed effects of changing landscapes on the distribution of mammals in Nebraska, including bats. As in adjacent portions of Kansas (Sparks and Choate 2000), most trees likely were cut during settlement, but tree cover increased as settlers eliminated the bison, suppressed fire, and planted trees.

METHODS

We netted for bats at 49 mist net sites (Fig. 1; Appendix 1) within and adjacent to upland and riparian woodlands 7 June – 14 August 2014. At each site we placed two net sets across travel corridors such as streams, trails, field margins, and small, infrequently used roads. Each set of nets consisted of one to three nets (6 - 18 m long and 2.6 m high) stacked vertically, to form a wall of netting across the corridor; stacked nets were counted as a single net, regardless of the number of nets staked or their length. We sampled each site on two nights (for a total of four net nights per site) unless rain forced us to stop and repeat that night's effort. As such, we accrued 156 complete and six partial net nights at 49 net sites with 11, 24, and 14 sites in Richardson, Nemaha, and Otoe counties, respectively. Sampling began at dusk and continued for 5 h until about 0200 h. Sampling efforts were based on USFWS guidance (USFWS 2014a). Bats captured were identified to species and the sex, reproductive condition, age, mass, length of right forearm, and time and location/net site of capture were recorded. Capture of volant young or pregnant, lactating, or post-lactating females was considered evidence of reproduction. Handling and care of captured bats followed guidelines for use of mammals in research (Sikes et al. 2011), and we followed the USFWS WNS protocols for summer sampling (current as of 25 January 2011). To locate roosts of the northern long-eared bat and obtain roost counts, we attached 0.25-g radio transmitters (Blackburn Transmitters®; Nacogdoches, Texas) using non-toxic surgical cement (Torbot Group®, Inc.; Cranston, Rhode Island) to an adult male and a non-reproductive female. We released the bats at the net site and tracked them to roosts using 3- and 5-element folding Yagi antennas (Wildlife Materials®; Murphysboro, Illinois) connected to a TRX-2000S PLL Synthesized Tracking Receiver (Wildlife Materials®, Inc.; Murphysboro, Illinois) or a Model R2000 Scanning Receiver (Advanced Telemetry Systems, Inc.; Isanti, Minnesota). We searched for roosts for eight days, and when a tree was located, we mapped the location, identified the species of tree, measured the diameter at breast height (DBH), approximated heights of both tree and roost, and visually estimated the amount of exfoliating bark and level of solar exposure (inverse of canopy cover). We conducted four roost counts per roost during the period 25 – 30 July 2014, counting bats as they left the roost at dusk.

We descriptively compared captures across species and between adult males and reproductive females. We assessed capture success using catch per net night, catch per net site, species per net site, and number of net sites where bats were caught. We calculated site-specific and collective species diversity indices (SDI): $SDI = 1/\sum P_i^2$, where P_i is the proportion of bats belonging to species *i* in each sample (MacArthur 1972). The SDI metric represents the number of equally represented species. We defined species richness as the number of species captured. We compared these metrics to those obtained using similar sampling methods at several study locations in forests of the eastern U.S.

RESULTS AND DISCUSSION

We captured 183 bats representing five species (Table 1). Eastern red bats accounted for 56 % (*n* = 103) of captures, big brown bats 26 % (*n* = 47), evening bats 15 % (*n* = 27), hoary bats 2 % (*n* = 4), and northern long-eared bats 1 % (*n* = 2). Species were not evenly represented in the captures, with eastern red bats comprising more than half of the captured sample (Table 1).

The mean rate of capture was 3.7 bats/net site (*SD* = 4.8) and 0.9 bats/net night (*SD* = 1.8). No bats were captured at 13 net sites, and only one bat was caught at 8 sites. The greatest number of bats captured at a site was 22 (Site 3), followed by 14 (Sites 25 and 41), 13 (Site 26), and 10 (Sites 4, 27, and 42) individuals. Species richness was greatest at eight sites (4, 22, 25, 26, 41, 42, 43, and 46) where three species were

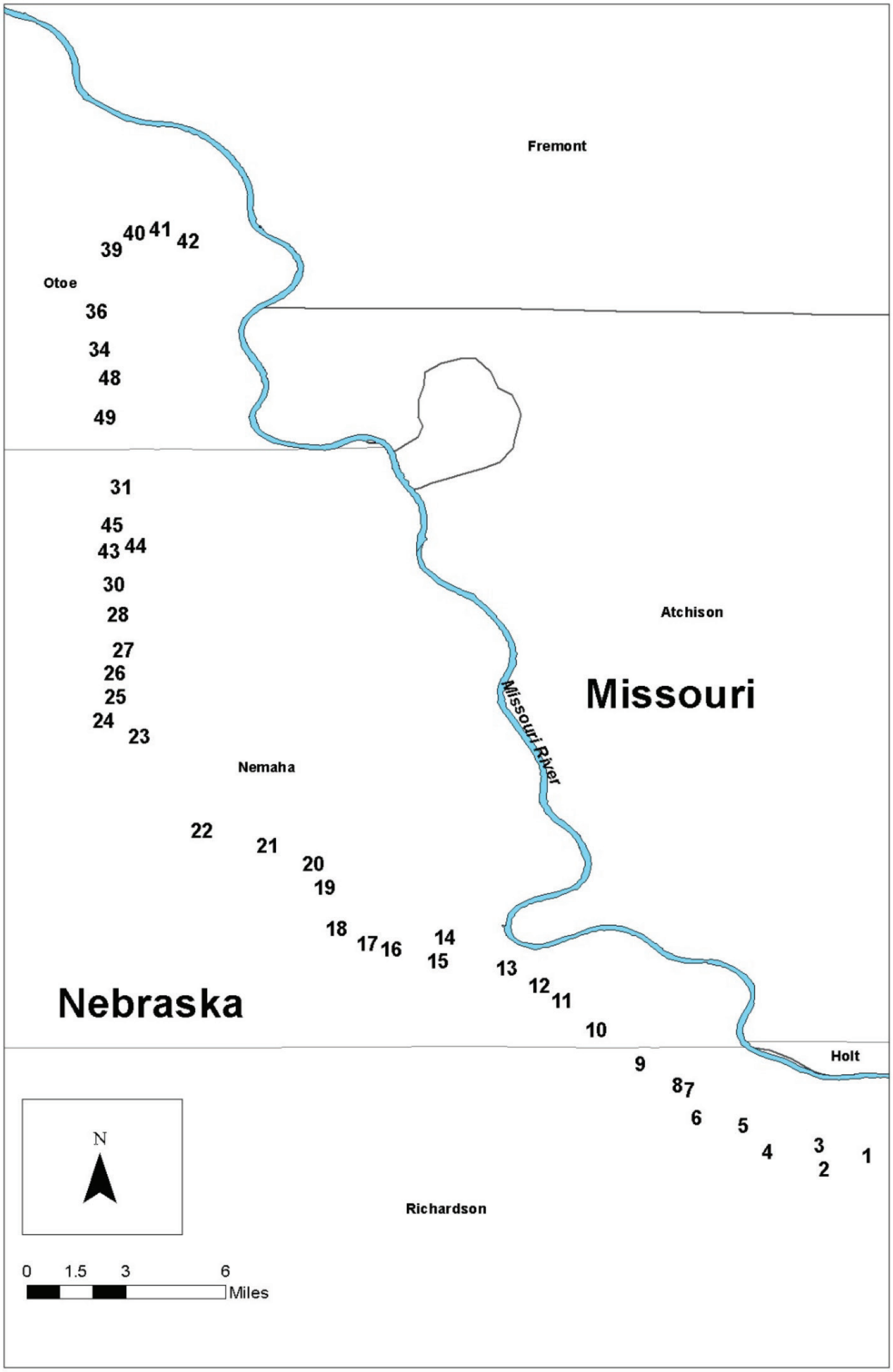

Figure 1. Locations of 49 mist net sites in Richardson, Nemaha, and Otoe counties, Nebraska, 2014.

Table 1. Captures of adult male, pregnant (P), lactating (L), post-lactating (PL), and non-reproductive (NR) adult female, and juvenile (Juv) bats at 49 sites in Richardson, Nemaha, and Otoe counties, Nebraska, 2014. Bats identified to species that escaped before sex and morphometric data were collected are noted (Escape).

Species	Male	P	L	PL	NR	Juv	Escape	Total
Big brown bat	14		6	6	1	17	3	47
Eastern red bat	5	16	12	14	4	44	8	103
Hoary bat			1			2	1	4
Northern long-eared bat	1				1			2
Evening bat			6	5		16		27
Total	20	16	25	25	6	79	12	183

captured. Overall, 1.3 (*SD* = 1.0) species were caught per net site, and the collective SDI was 2.5. Among sites, the SDI ranged from 0 to 2.8 ($\bar{x}$ = 1.5; *SD* = 0.6). Eastern red bats were captured at the most sites (*n* = 30; 61 % of sites), big brown bats were captured at about half as many sites (*n* = 17; 35 %), and other species were captured sporadically. We observed a sex bias between captures of adult male and female eastern red bats and evening bats, but not big brown bats (Table 1). Among adults, female eastern red bats were nearly eight times as common as males, and no adult male evening bats were captured. We obtained evidence of reproduction for all species captured in the study area except the northern long-eared bat.

Eastern Red Bat

The eastern red bat is a common summer resident throughout Nebraska (Czaplewski et al. 1979, Jones et al. 1983, 1985, Benedict 2004, Johnson and Geluso 2017). This was our most abundant species, as it was captured twice as frequently as any other species (Table 1) and at the most net sites. Our study provides a geographic distribution record for Nemaha County, although records exist in surrounding counties (Benedict 2004, Johnson and Geluso 2017). Far more reproductive females than adult males were captured in this study. Differences in sex ratios of red bats have been attributed to migratory patterns (LaVal and LaVal 1979) and to differences in temperature (and/or elevation) during the season of reproduction (Brack et al. 2002, Ford et al. 2001).

Big Brown Bat

The big brown bat is widely distributed across North America and Nebraska, and it was the second most frequently captured species. It is thought to reproduce statewide (Czaplewski et al. 1979, Jones et al. 1983, 1985, Benedict 2004, Geluso et al. 2004b, 2013, Geluso 2006, Serbousek and Geluso 2009, Johnson and Geluso 2017) and is not known to migrate long distances (Jones et al. 1983). Captures of reproductive individuals in Otoe (Sites 36, 37, 41, and 42) and Nemaha counties (Sites 22-26, 28, and 46) provided the first records of reproduction in those counties. Females often form maternity colonies where males are absent or much less common than females (Sparks and Choate 2000). As such, disparate sex ratios often are encountered among specific locations or net sites, although at a larger scale, sexes are often similarly common. In this study, adult males and reproductive females were similarly represented in the catch, similar to Fort Leavenworth, Kansas (Brack et al. 2007), but about a third of the sites that produced this species caught only males, a third produced only reproductive females and/or juveniles, and a third produced both adult males and reproductive females and/or juveniles. The big brown bat uses a variety of vegetation types and roosts (Duchamp et al. 2004), including natural and anthropogenic structures, which may mean the species is more common on the Plains now than pre-settlement (Sparks and Choate 2000).

Evening Bat

In Nebraska, the evening bat is most common in the southern and eastern portions of the state (Benedict 2004, Johnson and Geluso 2017). This species has been expanding its range to the west and north, including Nebraska (Geluso et al. 2008, Johnson and Geluso 2017) and Kansas (Sparks and Choate 2000, Sparks et al. 2011). Our study indicates the species is now common in the Loess Hills, with geographic and reproductive records at Site 4 in Richardson County, Sites 40 and 41 in Otoe County, and Sites 16, 22, 25, 26, 27, 43, 46, and 31 in Nemaha County. Adult males were not captured, which is typical of the northern and western portion of the range; the only nearby record from Kansas is from an upland site at Fort Leavenworth, Kansas (Davis 2005, Davis and Boyles 2005, Brack et al. 2007).

Hoary Bat

Hoary bats occur and reproduce statewide, but records do not indicate that this summer woodland resident is common anywhere in Nebraska (Benedict 2004), or generally elsewhere across its wide geographic distribution. Cryan (2003) indicated that during summer, males are mainly distributed in areas west of Nebraska and females are more common in the East, while Hayes et al. (2015) suggested that the range of female hoary bats might extend farther north and be more restricted to the interior of the continent than males. Captures of a lactating female at Site 13 and two juveniles at Site 16 in southeastern Nemaha County represent geographic and reproductive county records. Barbour and Davis (1969) reported this species frequently flies at heights in excess of 60 m so the species may be poorly sampled by typical mist-netting techniques. Using nets up to 20 m high, Brack (1983) found that 50 % of captures were at heights >8.3 m, but our equipment reached only to 7.8 m. High mortality rates at wind energy facilities (Arnett et al. 2008) suggest the species is more common than indicated from netting.

Northern Long-eared Bat

The northern long-eared bat is considered relatively uncommon throughout the plains states (Czaplewski et al. 1979, Bee et al. 1981, Jones et al. 1983, 1985), but in recent decades, pre-WNS, its abundance and distribution may have been increasing (Sparks and Choate 2000, Geluso et al. 2015). In Nebraska, the species has been found most commonly in the eastern third of the state (Benedict 2004, Geluso et al. 2004b), including a recent acoustic survey on an anthropogenic landscape of southeastern Nebraska (White et al. 2016). The acoustic survey included areas adjacent to our study area, and the survey determined the calls of this species were positively associated with the proportion of forested landscape within 2000 m of sampling stations (White et al. 2016). Stein and White (2016) indicated the species is expected throughout the region.

On 23 July 2014, we captured and radio-tagged an adult male and a non-reproductive adult female at net Site 42 in Otoe County. Both radio-tagged bats were tracked to separate cottonwood trees along the Missouri River. The female was tracked to a heavily wooded levee in Fremont County, Iowa, 3.43 km northeast of the net site, and the male was tracked to the edge of an open, sparsely wooded industrial site in Otoe County, 2.06 km east of the net site (Table 2). The two roost trees were separated by 2.41 km and the Missouri River. Each tagged bat occupied an identified roost only on the first of four nights when emergence counts were completed (Table 2). We did not detect the two tagged bats switching between the two known roosts, indicating the likely presence of additional nearby roosts (Johnson et al 2012). We never documented more than three bats emerging from either roost. Although our roost documentation is consistent with patterns of roost occupation by maternity colonies (Johnson et al 2012) and consistent with determination of a probable maternity colony for ESA regulatory compliance (USFWS 2014b), we do not have direct evidence of reproduction by the northern long-eared bat in the study area.

Northern long-eared bats regularly roost in live and dead trees. Summer maternity colonies are usually under sloughing bark or in hollows of trees, making characteristics of our two roost trees similar to those documented in past studies (Foster and Kurta 1999, Perry and Thill 2007, Johnson et al. 2012). Both roosts were cottonwoods in riparian areas, but they otherwise differed in characteristics. One was a large (DBH = 40 cm), partially dead tree, with only 10 % solar exposure. The other was smaller (DBH = 10 cm), completely dead, and had extensive (75 %) solar exposure. These differences are not surprising given the wide variety of roosts used by northern long-eared bats (Whitaker et al. 2006, Perry and Thill 2007, Timpone et al. 2010, Johnson et al. 2012). A wide variety of deciduous and coniferous tree species are used by maternity colonies, indicating that tree form, not species, is important for roosts (Carter and Feldhamer 2005).

Use of tree-roosts suggests that in the Plains portion of the range, northern long-eared bats should be found most commonly in wooded riparian corridors (Sparks and Choate 2000, Brack et al. 2007). This is in contrast to heavily wooded landscapes in Indiana, Missouri, and West Virginia, where the species is common in both riparian and upland wooded habitats and may be most abundant on non-riparian and upland sites (Brack and Whitaker 2001, Brack et al. 2005).

Species of Possible Occurrence

We did not capture the Indiana bat, which is unknown in Nebraska, but is apparently at the edge of its range a short distances to the east in Missouri and Iowa, or the Brazilian free-tailed bat, which is an uncommon visitor to southeastern

Table 2. Locations, characteristics, and dusk emergence counts of two roost trees used by radio-tagged northern long-eared bats in southeastern Nebraska, 2014.

Roost	Non-reproductive female	Adult male
Location	Extensive levee woodlot along the Missouri River, Freemont Co., IA	Small, disturbed floodplain woodlot, Otoe Co., NE
Distance, direction from capture site	3.4 km east-northeast	2.1 km east
DBH	40 cm	10 cm
Condition	Partially dead; 5 % exfoliating bark	Dead; 15 % exfoliating bark
Canopy Closure	90 %	25 %
Height	5 m	14 m
Four emergence counts	1, 3, 0, 0	3, 3, 0, 0

Nebraska in late summer (Genoways et al. 2000). Likewise, we did not capture silver-haired, little brown, or tri-colored bats that are considered residents of southeastern Nebraska (Czaplewski et al. 1979, Jones et al. 1983, 1985, Benedict 2004).

The silver-haired bat is a spring and autumn migrant in Nebraska, but recent studies (e.g., Geluso et al. 2004a, 2004b, 2013) documented reproduction, including in adjacent counties of Lancaster and Sarpy to the north. Our failure to capture this species during the summer season of reproduction indicates it likely does not occupy the study area in summer. The little brown bat is widely distributed across the U.S., and although abundant in the East, is uncommon or absent in much of its range, including the plains states. The species occupies and reproduces in two geographically separate areas of southeastern and northwestern Nebraska (Webb and Jones 1952, Czaplewski et al. 1979, Benedict 2004, Geluso et al. 2013). There are records in four of eight counties adjacent to the study area in Nebraska (Benedict 2004) and Kansas (Sparks et al. 2011). The species is apparently absent from the study area. The pre-Columbian distribution of the tricolored bat in the Plains States was limited (Sparks and Choate 2000) by its use of woodlands in summer (Veilleux et al. 2003) and underground hibernacula in winter, and both have increased as a result of anthropogenic activities. As a result, the bat's range is expanding (Geluso et al. 2005, Adams et al. 2018) and it is a resident of southeastern Nebraska and eastern Kansas (Czaplewski et al. 1979, Jones et al. 1985, Sparks and Choate 2000). Despite failing to capture the species in the study area, acoustic data from White et al. (2016) predicts the species is a likely summer resident of southeastern Nebraska.

A Comparison to Similar Studies in Eastern Hardwood Forests

For this study, the rate of capture, bats per net night, and bats per net site were lower than at Fort Leavenworth, Kansas (Brack et al. 2007; Table 3), which is also on the western edge of the eastern forest biome. Compared to similar studies in eastern forests, the capture of 0.9 bats per net night was markedly lower, as was 3.7 bats per net site (Table 3). While a variety of factors affect the catch rate, a lower rate of catch may often reflect lower abundance. Because this study and those to which it is compared followed a similar sampling protocol, it is a reasonable inference that bat abundance is relatively low in this study area.

Species richness in southeastern Nebraska was lower than all but one other site to which it is compared (Table 3). Species richness often increases with the level of sampling effort (Caughley 1965) and with habitat quality (Cable et al. 1989), whereas small, isolated habitat patches often do not retain a high species complement (MacArthur and Wilson 1967, Simberloff 1974, Janzen 1983). Finally, sampling more vegetation types is likely to increase the number of

Table 3. Capture success compared to similar studies in woodlands of the eastern and midwestern United States.

Location	Bats/net night	Bats/net site	MacArthur's Diversity Index*	Species richness	Sample sites; area; and timeline	Source
Richardson, Nemaha, and Otoe Co., NE	0.9	3.7	2.5	5	49 sites; long linear; 1 season 2014	Current Study
Ft. Leavenworth, KS	2.9	9.4	1.6	6	21 sites; large area; 3 seasons 1983 -2003	Brack et al. 2007
Crane, IN	1.8	5.6	4.4	8	99 sites; large area; 3 seasons 1987-1998	Brack and Whitaker 2004
Hoosier NF, IN	2.1		4.3	10	72 sites; large area; 5 seasons 1981-1999	Brack et al 2004
Ravenna, OH	2.4	9.7	2.9	6	28 sites; large area; 1 season 2004	Brack and Duffy 2006
Potter and McKean Co., PA & Cattaraugus Co., NY	2.9	12.1	2.3	5	55 sites; long linear; 1 season 2005	Brack 2009
Cumberland Plateau and Ridge & Valley Provinces, VA	1.9	7.8	3.9	11	201 sites; multiple linear in large area; 8 season 2000-2009	Timpone et al. 2011
Camp Dawson, WV	1.4	6.1	4.0	6	15 sites; large area; 1 season 2002	Brack et al. 2005
SE Virginia	2.3	5.6	2.0	6	11 sites; large area; 2 seasons 1995-1996	Hobson (1998)

* SDI = $1/\Sigma P_i^2$ (MacArthur 1972)

species encountered. However, this study and those to which it is compared, are similar in that most were completed across large study areas, often with a substantial survey effort (11 – 201 sample sites). All surveys sampled woodland habitat, both riparian and upland, and while there are geographic differences in woodlands of Nebraska and more eastern states, that is in part the point of this comparison. Thus, it is a reasonable inference that species richness is relatively low in our study area, equal to that of the northern-most study area in the east (i.e., northern Pennsylvania and southern New York; Table 3).

Species diversity is a measure that combines the importance of abundance and richness. Specifically, the MacArthur (1972) index we used provides a metric representing the number of equally represented species. Our species diversity was greater than Fort Leavenworth, Kansas (Brack et al 2007; Table 3). However, both our study and the one in Kansas had lower diversity indices than six out of seven studies conducted in the eastern U.S. (Table 3). Biomes reflect the distributions of a broad range of fauna and flora, so it might be expected that bat species diversity would be lower at the westernmost extent of the eastern deciduous forest biome.

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Appendix 1. Coordinates for 49 mist net sites in Richardson, Nemaha, and Otoe counties, Nebraska, 2014.

Site No.	Latitude	Longitude
1	N40° 12' 51.181"	W95° 30' 3.117"
2	N40° 12' 43.420"	W95° 31' 10.395"
3	N40° 12' 54.906"	W95° 31' 17.801"
4	N40° 12' 57.110"	W95° 32' 39.206"
5	N40° 13' 38.008"	W95° 33' 18.304"
6	N40° 13' 50.210"	W95° 34' 31.703"
7	N40° 14' 34.109"	W95° 34' 43.117"
8	N40° 14' 41.725"	W95° 35' 1.080"
9	N40° 15' 15.304"	W95° 35' 59.304"
10	N40° 16' 8.610"	W95° 37' 9.002"
11	N40° 16' 54.648"	W95° 38' 6.514"
12	N40° 17' 19.008"	W95° 38' 38.798"
13	N40° 17' 46.509"	W95° 39' 29.601"

Site No.	Latitude	Longitude
14	N40° 18' 21.501"	W95° 41' 6.607"
15	N40° 18' 7.692"	W95° 41' 17.704"
16	N40° 18' 15.445"	W95° 42' 34.128"
17	N40° 18' 25.026"	W95° 43' 7.703"
18	N40° 18' 48.111"	W95° 43' 56.495"
19	N40° 20' 1.715"	W95° 44' 15.414"
20	N40° 20' 30.541"	W95° 44' 33.501"
21	N40° 20' 58.702"	W95° 45' 45.602"
22	N40° 21' 22.499"	W95° 47' 28.503"
23	N40° 23' 50.637"	W95° 49' 7.112"
24	N40° 24' 25.616"	W95° 50' 2.201"
25	N40° 24' 55.111"	W95° 49' 44.092"
26	N40° 25' 41.512"	W95° 49' 45.601"

Site No.	Latitude	Longitude
27	N40° 26' 6.812"	W95° 49' 31.797"
28	N40° 27' 3.425"	W95° 49' 39.982"
29	N40° 27' 25.928"	W95° 49' 37.403"
30	N40° 27' 47.404"	W95° 49' 46.100"
31	N40° 30' 23.121"	W95° 49' 35.806"
32	N40° 31' 24.806"	W95° 49' 48.797"
33	N40° 31' 28.513"	W95° 49' 47.200"
34	N40° 33' 59.133"	W95° 50' 9.108"
35	N40° 34' 34.511"	W95° 50' 6.692"
36	N40° 34' 48.501"	W95° 50' 13.398"
37	N40° 35' 41.513"	W95° 49' 34.800"
38	N40° 35' 46.603"	W95° 49' 36.600"
39	N40° 36' 36.107"	W95° 49' 43.501"
40	N40° 37' 1.904"	W95° 49' 13.799"
41	N40° 37' 8.115"	W95° 48' 32.495"
42	N40° 36' 50.032"	W95° 47' 49.818"
43	N40° 28' 41.436"	W95° 49' 42.780"
44	N40° 28' 50.563"	W95° 49' 30.088"
45	N40° 29' 37.952"	W95° 49' 48.592"
46	N40° 29' 46.533"	W95° 49' 47.026"
47	N40° 32' 36.480"	W95° 49' 55.993"
48	N40° 33' 13.726"	W95° 49' 52.496"
49	N40° 32' 19.305"	W95° 49' 59.799"

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Serological Survey and Pathogen Exposure of Adult Female White-tailed Deer in the Western Dakotas

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ABSTRACT Establishing baseline values for pathogen exposure and nutritional indices is necessary to monitor population health. However, little is known about white-tailed deer (*Odocoileus virginianus*) pathogen exposure and nutritional condition in the Northern Great Plains. Our objective was to assess pathogen exposure and establish nutritional indices for female white-tailed deer in Dunn and Grant counties, North Dakota and Perkins County, South Dakota. During 2014, we collected blood serum from 150 adult female white-tailed deer. Pathogens with the highest antibody prevalence included West Nile Virus (WNV; 85%), epizootic hemorrhagic disease (48%), and malignant catarrhal fever (32%). Serum values for creatine kinase, globulin, glucose, potassium, and lactate dehydrogenase in all three study areas were higher than reference ranges while sodium was low in Grant County relative to Dunn and Perkins counties. We speculate that high exposure of WNV and high potassium values combined with low sodium values may affect neonate survival in Grant County. However, regional differences in pathogen exposure, their connection to serum values, and their potential interactive effects on survival are not well understood.

KEY WORDS: disease, epizootic hemorrhagic disease, livestock pathogens, nutritional indices, Northern Great Plains, *Odocoileus virginianus*, white-tailed deer, West Nile virus.

Nutritional indices and pathogen exposure rates are important components when assessing wildlife health. Nutritional indices are used to assess forage and habitat quality as well as reproductive state of white-tailed deer (*Odocoileus virginianus*; White and Cook 1974, Seal et al. 1981, Gill et al. 2001). Also, disease antibodies provide an assessment of past exposure to pathogens (e.g., bovine viral diarrhea virus, bluetongue virus, epizootic hemorrhagic disease; Gilbert et al. 2013). Further, white-tailed deer are sentinels for human and livestock related diseases (Gill et al. 1994, Wolf et al. 2008, Sherrill et al. 2012) and can facilitate disease transmission (Roug et al. 2012, Myers et al. 2015). Therefore, monitoring health factors and establishing baseline nutritional indices and pathogen exposure provides essential herd health information that may help explain population trends (Myers et al. 2015).

Antibody prevalence indicates previous exposure to an antigen but does not indicate current infection (Gilbert et al. 2013). Pathogen exposure can impact wildlife populations, domestic livestock, and human health (Wolf et al. 2008, Billinis 2012, Roug et al. 2012, Sherrill et al. 2012) by affecting factors such as reproduction and survival. For example, epizootic hemorrhagic disease and bluetongue virus are diseases that could impact ungulate population dynamics as infection often occurs during the breeding season and can be lethal (Dubay et al. 2006). Monitoring antibody prevalence in ungulate species is important in the western United States because livestock roam large tracts of land, which increases risk of disease transmission when compared to areas where cattle are confined (Wolf et al. 2008). Likewise, humans can become infected with pathogens carried by white-tailed deer such as *Anaplasma* and *Borrelia* (Wolf et al. 2008). Although pathogen exposure can have wide ranging effects, no pathogen exposure information has been reported for white-tailed deer inhabiting the rangelands of the western Dakotas.

Nutritional indices are used to monitor trace elements and minerals present in blood to evaluate seasonal health and nutrition (Seal et al. 1981, DelGiudice et al. 1987, DeLiberto et al. 1989) and are helpful when investigating forage nutritional value, reproduction, and survival (DelGiudice et al. 1991). For example, comprehensive nutritional analyses have been reported for white-tailed deer in Kansas (Klinger et al. 1986), southern Texas (White and Cook 1974), and North Carolina (Chitwood et al. 2013). Also, DelGiudice et al. (1991) investigated seasonal hematological differences of white-tailed deer in northern Minnesota, while Wolf et al. (2008) reported selenium values in female white-tailed deer in southern Minnesota. Seal et al. (1981) stressed the need for reference ranges for specific populations of white-tailed deer to accurately assess population health and to compare health across white-tailed deer populations in the United States. Although Zimmerman (2004) investigated impacts of burning on nutritional indices of white-tailed deer and mule deer (*O. hemionus*) in the southern Black Hills, South Dakota, USA, there are no published nutritional indices for white-tailed deer inhabiting the grasslands region of the western Dakotas.

Our objectives were to establish baseline information on nutritional indices and pathogen exposure for adult female white-tailed deer in western North Dakota and northwestern South Dakota. We measured nutritional indices for several minerals including sodium (Na), phosphorus (P), and magnesium (Mg), given their potential impacts on spatial distribution and carrying capacity (McNaughton 1988, Freeland and Choquenot 1990), seasonal movements (McNaughton 1990), and diet selection (Furness 1988) of ungulates. We then chose to compare our baseline information from the Dakotas to similar information provided by Seal et al. (1981; Minnesota), Tumbleson et al. (1968; Missouri), and Chitwood et al. (2013; North Carolina). Similarly, we measured exposure to several pathogens that can have population level impacts on white-tailed deer, including epizootic hemorrhagic disease (Fischer et al. 1995, Gaydos et al. 2004) and chronic wasting disease (CWD; Edmunds et al. 2016), as well as pathogens that are transmissible between domestic livestock and white-tailed deer (e.g., malignant catarrhal fever [MCF; Li et al. 2013, Palmer et al. 2013]).

STUDY AREA

We assessed female white-tailed deer pathogen exposure and nutritional indices in Grant and Dunn counties, North Dakota, and Perkins County, South Dakota (Fig. 1), during 2014. The three study areas were located in the Northwestern Great Plains Level III Ecoregion (Bryce et al. 1998).

In Dunn County, we captured white-tailed deer in a 1,492 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas comprised 60, 20, and 9% of the land cover, respectively (U. S. Department of Agriculture 2015), and white-tailed deer density was estimated at 1.0 deer/km^2 in 2011 (Stillings et al. 2012). Thirty-year mean annual precipitation was 41.4 cm, and thirty-year mean monthly temperature ranged from -15.1^{o}C to 29.3^{o}C (North Dakota State Climate Office 2016). Cattle and sheep densities were 14.8 cattle/km^2 and 0.3 sheep/km^2 during 2012 (U. S. Department of Agriculture 2014). Oil and natural gas development was prevalent, with ~1,800 active oil wells in Dunn County that produced about 64 million barrels of oil and 35 million cubic feet of natural gas annually (Department of Mineral Resources 2016).

In Grant County, we captured white-tailed deer in a 1,865 km^2 area in the southwestern portion of the county. Grasslands, cropland, and forested areas comprised 68, 26, and 1% of the land cover, respectively (U.S. Department of Agriculture 2015), and white-tailed deer density was estimated at 1.8 deer/km^2 in 2011 (Stillings et al. 2012). Thirty-year mean annual precipitation was 41.2 cm, and thirty-year mean monthly temperature ranged from -14.4^o C to 29.7^{o}C (North Dakota State Climate Office 2016). Cattle and sheep densities were 17.8 cattle/km^2 and 0.5 sheep/km^2 during 2012 (U.S. Department of Agriculture 2014). From 2009 to 2016, chronic wasting disease was detected in 1 white-tailed deer and 8 mule deer in Grant County. There was no active oil and natural gas development in Grant County during our study.

In Perkins County, we captured white-tailed deer in a 1,492 km^2 area in the central portion of the county. Grasslands, cropland, and forested areas comprised 86, 11, and 0.01% of the land cover, respectively (U.S. Department of Agriculture 2015), and white-tailed deer density was estimated at 1.2 deer/km^2 in 2015 (K. Robling, South Dakota Game, Fish and Parks, personal communication). Thirty-year mean annual precipitation was 44.9 cm, and mean thirty-year monthly temperature ranged from -12.1^o C to 30.3^o C (North Dakota State Climate Office 2016). Cattle and sheep densities were 14.1 cattle/km^2 and 2.0 sheep/km^2 during 2012 (U.S. Department of Agriculture 2014). There was no active oil and natural gas development in Perkins County during our study.

METHODS

We captured female (≥ 9 month-old) white-tailed deer via helicopter net guns (Native Range Capture Services, Elko, NV, USA) from 24 February to 2 March 2014. We hobbled, blindfolded, radio-collared, and collected blood at capture locations; we collected about 20 ml of blood from each white-tailed deer via jugular venipuncture from all study areas. All capture and handling methods were approved by the Institutional Animal Care and Use Committee at South Dakota State University (13-091A) and followed guidelines for care and use of mammals established by the American Society of Mammalogists (Sikes et al. 2016).

We maintained blood vials at room temperature and allowed them to clot before centrifugation. Following centrifugation, we separated serum from cells via pipette and placed serum in cryovial tubes. We sent serum samples to the North Dakota State University (NDSU) Veterinary Diagnostic Laboratory for analysis (NDSU, Fargo, ND, USA). We prioritized which nutritional indices to run based on previous literature (Seal et al. 1981, Tumbleson et al. 1968, Chitwood et al. 2013). We analyzed serum samples for alkaline phosphatase (IU/L), aspartate aminotransferase (IU/L), albumin (ALB, g/dL), blood urea nitrogen (BUN, mg/dL), calcium (Ca, mg/dL), chloride (Cl, mEq/L), creatinine kinase (CK, md/dL), gamma-glutamyl transpeptidase (GGT, IU/L), globulin (GLOB, g/dL), glucose (GLU, mg/dL),

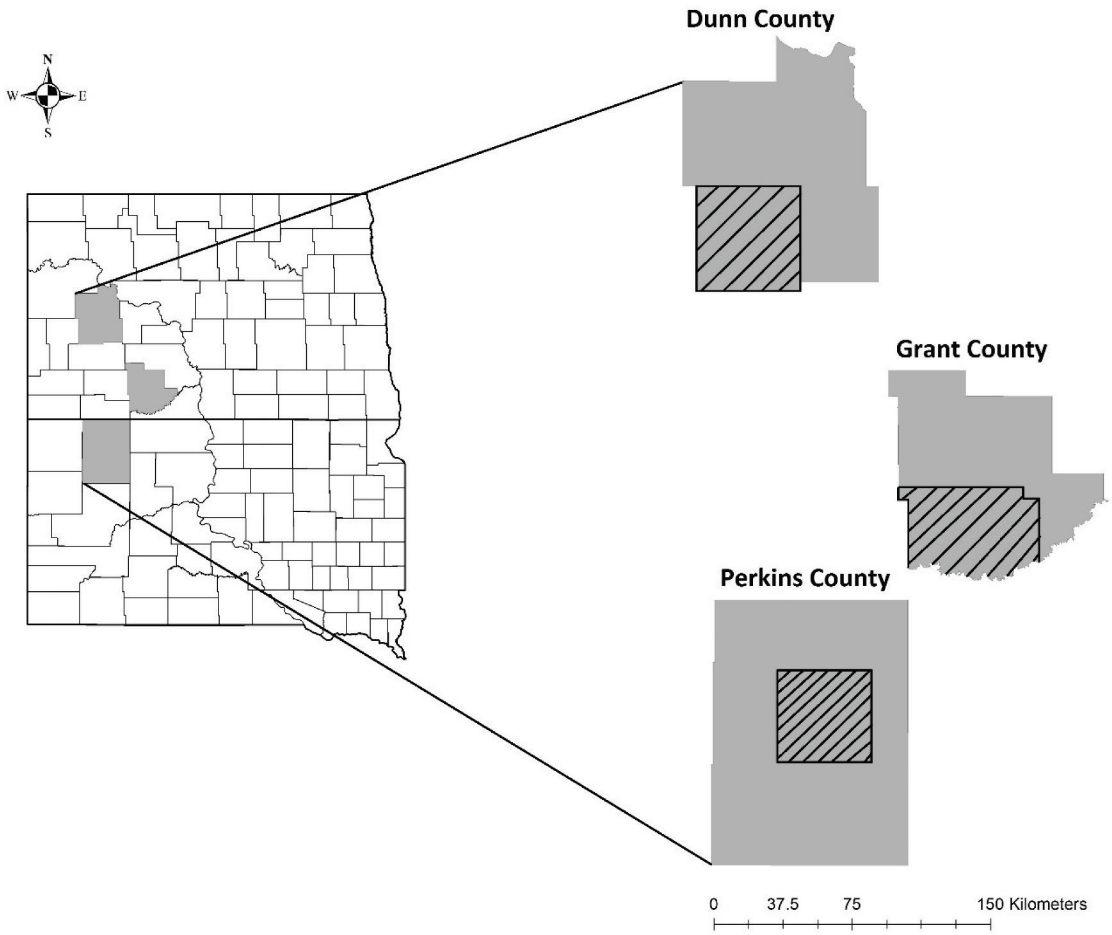

Figure 1. Study areas where adult female white-tailed deer (*Odocoileus virginianus*) were captured and radio-collared in Dunn and Grant counties, North Dakota, and Perkins County, South Dakota, USA. Dashed lines indicate deer capture areas within each county.

lactate dehydrogenase (LDH, IU/L), magnesium (Mg, mg/dL), phosphorus (P, mg/dL), potassium (K, mEq/L), sodium (Na, mEq/L), and total protein (TP, g/dL).

The Minnesota Veterinary Diagnostic Laboratory (University of Minnesota, St. Paul, MN, USA) determined disease status from serum samples. We tested serum for the following pathogens: *Anaplasma marginale*, *Borrelia spp.*, *Brucella abortus*, bovine parainfluenza – 3 virus (PI3), bovine viral diarrhea virus (BVDV) type 1 and 2, bluetongue virus (BTV), epizootic hemorrhagic disease (EHD), infectious bovine rhinotracheitis (IBR), six serovars of *Leptospira interrogans* (*bratislava*, *canicola*, *grippotyphosa*, *hardjo*, *icterohemorrhagica*, and *pomona*), and *Neospora* spp. We sent additional serum samples to the National Veterinary Services Laboratory (U.S. Department of Agriculture, Ames, IA, USA) to test for the following pathogens: malignant catarrhal fever (MCF), West Nile Virus (WNV), and eastern and western equine encephalitis (EEE and WEE, respectively). The Diagnostic Center for Population and Animal Health (currently known as Michigan State University Diagnostic Laboratory; Michigan State University, Lansing, MI, USA) tested lymph nodes from hunter-harvested radio-collared white-tailed deer for chronic wasting disease (CWD).

We used card agglutination to determine positive *A. marginale* titers at 1:320 and used indirect immunofluorescence assay (IFA) to determine positive *Borrelia* titers at 1:320. We used hemagglutination inhibition (HI) to determine positive PI3 titers at 1:10 and used serum neutralization (SN) to determine positive BVDV 1 and 2 and IBR titers at 1:8. We used a microscopic agglutination test (MAT) to determine positive *L. interrogans* (including serovars *bratislava*, *canicola*, *grippotyphosa*, *hardjo icterohemorrhagica*, and *pomona*) titers at 1:100. We used peroxide linked assay (PLA) to determine MCF positive titers at 1:20 and used immunoglobin M (IgM) and immunoglobulin G (IgG) to detect WNV titers at 1:10. We interpreted no agglutination in a sample to indicate a negative reaction for *B. abortus*.

We used an enzyme-linked immunosorbent assay (ELISA) to detect EEE and WEE titers at 1:10. We used

ELISA to detect *Neospora* spp. titers when sample to positive ratios (S:P) were greater than 0.50 and also used ELISA to test lymph nodes from mortalities for CWD. We used polymerase chain reaction (PCR) to detect BTV and EHD DNA presence.

Statistical analysis

We quantified antibody prevalence and nutritional index values to establish baseline information for female white-tailed deer in western North Dakota and northwestern South Dakota. We used a proportions analysis using the prop.test function in Program R (R Development Core Team 2017; version 3.3.1) to assess if pathogen exposure varied by study area. We used descriptive statistics and qualitative comparisons with other published values to assess whether or not white-tailed deer in North and South Dakota were in or out of normal ranges for nutritional index values.

RESULTS

We captured and collected blood from 50 adult female white-tailed deer in each county (totaling 150) and collected lymph nodes from nine hunter-harvested radio-collared deer. In Dunn County, antibodies for WNV (79%), EHD (40%), and MCF (24%) were most prevalent (all other antibodies were ≤ 12%; Table 1). Similarly, in Perkins County, antibodies for WNV (86%), EHD (81%), MCF (62%) were most prevalent (all other antibodies were ≤ 37%; Table 1). In Grant County, antibodies for WNV (89%), PI3 (45%), and IBR (22%) were most prevalent (all other antibodies were ≤ 10%; Table 1). We detected antibodies for all infectious agents except *Brucella* spp., *L. interrogans* serovars *canicola*, *hardjo*, and *icterohemorrhagica*, and eastern and western equine encephalitis. Observed titer levels were low for most pathogens except one individual with titers of 1:128 for BVDV 1, one individual with titer levels of 1:1600 for *L. interrogans* serovar *pomona*, and one individual with titer levels of 1:320 for PI3. None of the hunter-harvested radio-collared individuals tested positive for CWD (n = 9).

We documented variation in the nutritional indices that fell above, within, and below reference ranges. When comparing to Seal et al. (1981), mean Cl, CK, GGT, GLOB, LDH, and K were above reference ranges for all counties (Table 2). Mean P was above reference ranges in Dunn and Perkins counties and mean ALB was also above Seal et al. (1981) reference range in Perkins County. Mean BUN, Ca, GLU, Na, and TP were all within reference ranges

Table 1. Antibody prevalence (# positive/# tested) in female white-tailed deer in Dunn and Grant Counties, North Dakota, and Perkins County, South Dakota, during 2014.

		No. positive/total tested (%)		
Agent	No. positive/total tested (%)	Dunn	Grant	Perkins
Anaplasma marginale	5/118 (4%)	3/44 (7%)	2/29 (7%)	0/45
Borrelia spp.	14/146 (10%)	1/47 (2%)	3/49 (6%)	10/50 (20%)
Brucella abortus	0/131	0/36	0/49	0/46
Bovine Parainfluenza – 3 Virus (PI3)	33/114 (29%)	3/39 (8%)	13/29 (45%)	17/46 (37%)
Bovine Viral Diarrhea Virus Type 1 (BVDV 1)	3/150 (2%)	0/50	3/50 (6%)	0/50
Bovine Viral Diarrhea Virus Type 2 (BVDV 2)	2/150 (1%)	0/50	2/50 (4%)	0/50
Bluetongue Virus (BTV)	2/150 (1%)	0/50	0/50	2/50 (4%)
Epizootic Hemorrhagic Disease (EHD)	62/128 (48%)	20/50 (40%)	3/30 (10%)	39/48 (81%)
Infectious Bovine Rhinotracheitis (IBR)	28/150 (19%)	6/50 (12%)	11/50 (22%)	11/50 (22%)
L. i. grippotyphosa	1/150 (1%)	0/50	0/50	1/150 (2%)
L. i. bratislava	12/150 (8%)	3/50 (6%)	4/50 (8%)	5/50 (10%)
L. i. pomona	7/150 (5%)	5/50 (10%)	1/50 (1%)	1/50 (1%)
Malignant Catarrhal Fever (MCF)	33/103 (32%)	7/29 (24%)	3/37 (8%)	23/37 (62%)
Neospora spp.	5/117 (4%)	2/43 (5%)	2/29 (7%)	1/45 (2%)
West Nile Virus (WNV)	87/102 (85%)	23/29 (79%)	32/36 (89%)	32/37 (86%)
Eastern and Western Equine Encephalitis (EEE and WEE)	0/118	0/29	0/52	0/37
Chronic Wasting Disease (CWD)	0/9	0/1	0/7	0/1

Table 2. Nutritional indices for radio-collared female white-tailed deer in Dunn and Grant Counties, North Dakota, and Perkins County, South Dakota, during 2014.

	Dunn		Grant		Perkins		Reference Ranges	
Blood Chemistry Parameter	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Seal et al. (1981)	Chitwood et al. (2013)
Albumin (g/dL)	4.11 (0.05)	3.50-4.90	4.14 (0.05)	3.10-4.80	4.34 (0.18)	2.50-12	2.50-4.20	2.10-3.30
Alkaline Phosphatase (IU/L)	54.32 (3.04)	12-147	56.50 (2.04)	17-132	63.18 (3.66)	29-145	n/a	24-267
Aspartate Aminotransferase (IU/L)	154.96 (7.23)	75-344	175.30 (7.65)	72-317	198.58 (25.30)	93-1384	n/a	47-166
Blood Urea Nitrogen (mg/dL)	23.38 (1.01)	13-43	20.62 (0.85)	8.50-11.10	23.24 (0.97)	13.57	15-45	6-35
Calcium (mg/dL)	10.39 (0.61)	8.70-40.10	9.79 (0.07)	8.50-11.10	9.74 (0.12)	6.60-12	8.80-10.80	8.70-11.60
Chloride (mEq/L)	113.60 (0.52)	108-133	112.92 (1.25)	53-117	113.80 (0.38)	109-123	100-110	97-119
Creatinine Kinase (md/dL)	414.88 (38.10)	103-1486	614.92 (30.32)	196-1041	730.06 (46.70)	13-2007	20-400	63-1883
Gamma-Glutamyl Transpeptidase (IU/L)	118.84 (4.34)	50-231	116.36 (4.25)	50-247	111.92 (3.73)	80-227	40-100	n/a
Globulin (g/dL)	2.67 (0.04)	2.30-3.60	2.95 (0.06)	2.40-4.30	2.74 (0.04)	2.2-3.40	0.40-1.00	2.70-5.30
Glucose (mg/dL)	157.08 (4.64)	82-243	161.26 (4.89)	90-243	139.64 (5.77)	23-212	60-320	85-409
Lactate Dehydrogenase (IU/L)	1152.42 (49.93)	112-2377	1437.76 (76.73)	866-3486	1160.08 (46.25)	590-2800	100-300	n/a
Phosphorus (mg/dL)	8.92 (0.23)	5.80-12	8.15 (0.19)	5.00-10.50	8.63 (0.30)	2.94-13.80	4.50-8.50	5.60-15.50
Potassium (mEq/L)	12.70 (0.38)	8.90-14.80	13.50 (0.00)	13.5	25.19 (3.18)	12.90-50.81	3.40-5.00	5.80-12.00
Sodium (mEq/L)	152.50 (0.81)	133-161	140.34 (2.03)	61-157	146.38 (1.20)	127-161	132-156	139-171
Total Protein (g/dL)	6.78 (0.06)	6-7.90	7.09 (0.07)	5.80-8.50	7.12 (0.15)	6-13.50	5.00-7.80	5.30-8.20

reported by Seal et al. (1981) for all counties. Mean ALB was within reference ranges for Dunn and Grant counties, while mean P was within reference range for Grant County only. When comparing to Chitwood et al. (2013), only mean ALB and K were above reference ranges for all counties, while mean aspartate aminotransferase was above the reference range for Grant and Perkins counties, only. Mean alkaline phosphatase, Ca, Cl, CK, GLU, P, Na, and TP for all 3 counties were all within the reference range reported by Chitwood et al. (2013), while mean GLOB was within range for Grant and Perkins counties and mean aspartate aminotransferase was within range for Dunn County only. No mean nutritional indices were reported below reference ranges reported by Seal et al. (1981), while mean GLOB was the only nutritional index reported below the reference range for Chitwood et al. (2013). Mean Mg was greater in Dunn (2.81 mg/dL), Grant (2.94 mg/dL), and Perkins (3.04 mg/dL) compared to the reference range reported by Tumbleson et al. (1968; range = 2.2–2.6). Sufficient serum was available for most samples ($n \geq 146$) for assessing nutritional indices; however, given that we prioritized nutritional indices, some that were of lower priority had fewer samples. For example, samples available for assessing K were low for Dunn (n = 22), Grant (n = 1), and Perkins (n = 14) counties.

DISCUSSION

Pathogen exposure

Exposure of EHD ranged from 10% (Grant County) to 81% (Perkins County). Although exposure rates in Grant County were comparable to historic EHD exposure rates reported for North Dakota (7%; Sohn and Anderson 1991), we report greater exposure rates in Dunn (40%) and Perkins (81%) counties. North Dakota observed high white-tailed deer mortality attributed to EHD during 2008, 2011, and 2013; epizootics caused high mortality in Grant County with few reports in Dunn County, indicating differences in intensity of exposure across the landscape (North Dakota Game and Fish Department). Naïve white-tailed deer populations exposed to new strains of EHD may display increased mortality compared to white-tailed deer populations previously exposed to the same strain (Shope et al. 1960, Gaydos et al. 2002). Individuals in Grant County may not have been exposed to the strain(s) of EHD present on the landscape in 2008, 2011, and 2013, causing them to perish at an increased rate and removing them from the landscape during sampling. Conversely, if white-tailed deer in Dunn and Perkins counties were previously exposed to those strains and developed immunity allowing them to survive until our sampling effort, then they would have displayed increased antibody prevalence compared to white-tailed deer sampled from Grant County.

Our results indicate white-tailed deer are exposed to a number of livestock pathogens that are potentially influenced by farm operation type (Wolf et al. 2008). For example, most farm operations in the western Dakotas allow livestock grazing, which facilitates increased white-tailed deer exposure to livestock and disease transmission compared to farm operations that keep livestock contained. Exposure of MCF was highest in Perkins County compared to Dunn and Grant counties, which could be explained by its relatively higher sheep density (sheep were also allowed to graze; 2.0 sheep/km^2) compared to Dunn (0.3 sheep/km^2) and Grant (0.5 sheep/km^2) counties. Exposure of PI3 and IBR were higher in Perkins County than Dunn County but there was no difference in exposure between Perkins and Grant counties. We hypothesize that white-tailed deer in the western Dakotas come in contact with livestock and/or their feces on the landscape, increasing exposure to livestock pathogens.

We observed exposure to *Borrelia* spp. in all study areas with a relatively high exposure rate in Perkins County (20%) compared to Dunn (2%) and Grant (6%) counties. The high exposure rate in Perkins County was similar to levels detected in Minnesota (29%; Wolf et al. 2008). Wolf et al. (2008) attributed differences in *B. burgdorferi* antibody prevalence between study areas to one area providing more suitable habitat for *Ixodes scapularis*, but surveys in North and South Dakota show that *I. scapularis* is only present in eastern portions of the states (Russart et al. 2014, Maestas et al. 2016). The presence of *Borrelia* spp. may indicate that *B. burgdorferi* or *B. mayonii* were present; however, we did not specifically test for either species. Additionally, *B. mayonii* is relatively new to the landscape and its distribution is unknown (Pritt et al. 2016). Further investigation will help to clarify the cause of the *Borrelia* spp. antibody presence in the western Dakotas.

Although our results indicate that white-tailed deer in the western Dakotas are exposed to a variety of viruses, WNV exposure was consistently high (> 56%). White-tailed deer have tested positive for WNV in New Jersey, USA (Farajollahi et al. 2004) and Georgia, USA (Miller et al. 2005), but only one white-tailed deer mortality was linked to WNV (Miller et al. 2005). While avian species are affected severely, effects of WNV on ungulate species are not well understood, though Miller et al. (2005) suggested that WNV was not a threat to white-tailed deer populations. High WNV exposure could be related to the low neonate survival reported in Grant County (35%; Moratz 2016); however, we did not collect blood samples from dead neonates to verify cause of death. Nevertheless, we hypothesize that WNV infections could be related to neonate mortality if WNV acts as an additive stressor.

Nutritional indices

Several nutritional indices were above the reference ranges reported by Seal et al. (1981) and Chitwood et al. (2013). We observed greater than 42% of white-tailed deer across all sites with ALB, AST, and K values above reference ranges reported by Chitwood et al. (2013), while 35.6% and 17.6% of individuals displayed GLOB and Na values, respectively, below the reference ranges reported by Chitwood et al. (2013). We observed greater than 60% of individuals with Cl, CK, GGT, GLOB, K, LDH, and Mg values above reference ranges established by Seal et al. (1981), whereas less than 50% of individuals had ALB, Ca, Na, P, and TP values above reference ranges (Seal et al. 1981). We observed less than 10% of individuals with BUN, Ca, CK, Cl, GLU, Na, and P values below reference ranges (Seal et al. 1981).

There are several minerals that are not considered to be limiting in the environment. For example, Cl is generally not thought to be limited in the environment while Ca and Mg are readily available in forage (Barboza et al. 2009, Hewitt 2011) and wild ungulates are rarely deficient (Barboza et al. 2009). Our results support this as we observed over 80% of females with Cl and Mg values above reference ranges and more than 90% of females had Ca values within reference range (Seal et al. 1981). Although, P can be a limiting nutrient for herbivores because levels can be limited in forage (Hewitt 2011) we determined that 50% of females had P values within reference ranges (Seal et al. 1981) suggesting that P was not limited to females in our study. Winter Cl and P values in white-tailed deer in the southern Black Hills were similar to observed Cl and P values in white-tailed deer in our study areas, and Mg values for Grant and Perkins counties were similar to winter Mg values in the southern Black Hills (Zimmerman 2004). Calcium values in all study areas were higher than winter Ca values in white-tailed deer in the southern Black Hills (Zimmerman 2004). Therefore, our results suggest that forage availability likely varies among the reference area in Minnesota (Seal et al. 1981), the southern Black Hills (Zimmerman 2004), and western North Dakota and northwestern South Dakota.

High K values for free-ranging white-tailed deer are reported in the literature (DeLiberto et al. 1989, Zimmerman 2004, Chitwood et al. 2013), with K values varying considerably (although not in a predictable manner) due to K concentrations in available forage (DeLiberto et al. 1989, Zimmerman 2004), capture methodology (DeLiberto et al. 1989, Stringer et al. 2011), and blood sample handling (Stringer et al. 2011). Potassium values reported by Seal et al. (1981) ranged from 3.40 – 5.00 mEq/L and values reported by Chitwood et al. (2013) ranged from 5.80 – 12.00; however, in our study individuals ranged from 8.90 – 50.81, though we obtained small sample sizes for some study areas. Regardless, average winter K values in the southern Black Hills were also higher than average K values in our study (Zimmerman 2004). Intracellular K concentrations are important for cardiac excitability and neurotransmission (Carlson 1997), while extracellular K concentrations are tightly regulated within the body. The physiological impacts of high K values in white-tailed deer are unclear as individuals do not show negative effects at high levels (Stringer et al. 2011). Therefore, white-tailed deer appear to be able to consistently maintain high levels of K in free-ranging populations.

Growth and reproduction increases Na demands in female ungulates (Hellgren and Pitts 1997, Barboza et al. 2009). For instance, female Na requirements double those of males during gestation and lactation (Hewitt 2011). White-tailed deer females seek mineral licks in spring and summer to supplement deficiencies in dietary Na during gestation and lactation (Kennedy et al. 1995). However, we observed high K values in all study areas, and high K intake can prevent absorption of Na, exacerbating low Na levels (Weeks and Kirkpatrick 1976, Barboza et al. 2009). White-tailed deer fawn survival was lower in Grant County (35%) compared to Dunn and Perkins counties (93%; Moratz 2016). It is possible that increased K levels may be reducing absorption of Na, potentially becoming a limiting factor for reproduction in Grant County.

Our capture methods may have influenced the nutritional indices CK, GLOB, GLU, and LDH, which were above our comparative reference ranges (Seal et al. 1981). Individuals that are immobilized for handling often have lower CK and stress levels than those not immobilized (Montané et al. 2003); however, we did not immobilize individuals during capture, which potentially explains our high CK values. High GLOB, LDH, and GLU levels also can be attributed to high levels of stress in individuals (Rosef et al. 2004) and therefore, our high levels may be attributed to chase time and capture from helicopter net-gunning (Klinger et al. 1986, Smith 2011). However, GLU concentrations can also be highly variable in wild populations of white-tailed deer (Jenks et al. 1991, DePerno et al. 2015). Regardless, capture methods need to be considered before using CK, GLOB, LDH, and GLU as nutritional indices for white-tailed deer.

High GGT levels may indicate liver injury, which can result in reduced weight and performance in cattle (Moreira et al. 2012). Mean GGT values were similar among areas, but more than 45% of individuals displayed values outside of the reference range (Seal et al. 1981). Winter GGT in the southern Black Hills were lower than observed GGT values in all of our study areas. Effects of high GGT levels on white-tailed deer are unknown.

Our results provide new reference range data for white-tailed deer that can be used for comparison to other white-tailed deer populations across North America and for future herd health evaluation in the western Dakotas. Collecting blood samples from individual white-tailed deer over time and using a variety of capture methods would better provide information needed to determine the relationship between our results and herd health. Additional research is needed to identify potential differences in forage quality and availability among study areas that may be responsible for differences in nutritional indices documented during our study. Finally, more information is needed to better understand the transmission of many livestock pathogens between cattle and wildlife populations. Future research could also evaluate the potential impacts of WNV on white-tailed deer survival and reproduction.

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Factors Limiting Reintroduced Plains Topminnow, *Fundulus sciadicus*, Populations in Central Great Plains Streams

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ABSTRACT The plains topminnow (*Fundulus sciadicus*) is an endemic Great Plains stream fish that has experienced declines in geographic range and local abundance. Due to these declines, the species has been considered for federal protection and designated with conservation status in states throughout its historic range. The reasons for declines are likely similar to hypothesized factors for other endemic stream fish declines in the Great Plains. To investigate potential limiting factors a suite of 17 historic sites with reintroduced plains topminnow populations across Nebraska were evaluated for current populations and if plains topminnow were absent, additional fish were introduced. These sites were sampled for plains topminnow persistence with fall backpack shocking in 2014-2016. A suite of 10 abiotic and biotic variables were selected *a priori*, based on previous research and guidance from fisheries personnel with working knowledge of the species, to evaluate potential factors that regulate populations of plains topminnow following reintroductions. Variables were combined to develop models based on plains topminnow life history characteristics, trophic interactions, and habitat requirements. Competing models were compared and variables were prioritized using an information theoretic approach. Limited backwater pool habitat and high predator fish abundances have the greatest relative importance in limiting reintroduced plains topminnow populations. Future management efforts to reintroduce plains topminnow should prioritize locations with these available habitats and communities and habitat renovation efforts should focus on these identified parameters.

KEY WORDS: Great Plains, limiting factors, native fish, reintroduced, plains topminnow

The native freshwater stream fishes of North America are declining (Minckley and Douglas 1991, Saunders et al. 2002). Approximately 70% of freshwater fishes throughout North America are at risk of continued declines in both local abundances and distribution (Ricciardi and Rasmussen 1999, Fischer and Paukert 2008*a*, Smith et al. 2014). Multitudes of abiotic and biotic alterations have been postulated to negatively influence native fish populations and assemblage diversity across the US (Pierce et al. 2001, Rahel 2002, Fischer and Paukert 2008*b*). However, the identification of important threats to imperiled species is limited, and often hinders the establishment of effective conservation measures (Campbell et al. 2002).

Increased legal protection of imperiled fishes in North America has resulted in efforts to conserve, not only entire species, but also individual populations (Minckley 1995). Conservation strategies to protect populations of imperiled species have included minimum flow requirements, habitat preservation and reserves, habitat enhancements or restoration, repatriation, and predator fish removal (Marsh et al. 2005; Mueller 2005). The recovery of imperiled species commonly employs stocking strategies such as augmentations, translocations, and reintroduction in attempts to sustain or reestablish historic populations (Sheller et al. 2006, Schumann et al. 2017). However, the majority of reestablishment efforts fail to establish subsequent year-classes due to the lack of considerations for potential limiting factors (Minckley 1995). Assessing stocking and reestablishment feasibility prior to implementation would likely result in greater success (Dunham 2011). Identifying the biotic and habitat features that influence abundance after reintroduction can help to maximize capital investments and the probability of species reestablishment.

Plains topminnow (*Fundulus sciadicus*) is a Great Plains stream fish, which has experienced declines in range-wide distribution as well as measurable reductions in local abundance (Haas 2005, Fischer and Paukert 2008*a*, Pasbrig et al. 2012). Nebraska comprises over 60% of the species distribution, and currently lists plains topminnow as a Tier 1 at risk species (Schneider et al. 2011). Theoretically, plains topminnow should be resilient to changes that minimize their distribution. Plains topminnow are robust, and durable backwater specialists that tolerate a wide range of abiotic conditions (Rahel and Thel 2004). Plains topminnow demonstrate a large home range that can allow reestablishment of desiccated stream reaches (Schumann et al. 2015*b*) and seek calm, shallow, warm waters with prolific aquatic vegetation (Rahel and Thel 2004). The presence of stream crossing structures has been identified to create deeper pool habitat which favor predator fish such as green sunfish (*Lepomis cyanellus*) and largemouth bass (*Micropterus salmoides*), and potentially limit the ability to move upstream (Dodds et al. 2004). While plains topminnow are generalized feeders they do demonstrate a selective preference for gastropods (Thiessen et al. 2018), which are commonly associated with heavily vegetated aquatic habitats (Ross and Ultsch 1980), suggesting alterations in substrate composition and shifts in flow regimes that limit submerged vegetation may be important to plains topminnow persistence (Schumann et al. 2017).

A variety of conservation efforts for this species have been undertaken in Nebraska including the development of a cultivation pond (Schumann et al. 2012) and subsequent species reintroduction efforts (Schumann et al. 2017). Supplementing plains topminnow populations through stocking increases local abundance, maintains genetic diversity, and temporarily preserves the ecosystem's community value (Reading et al. 2002, Marsh et al. 2005). However, stocking efforts do not address the factors prompting population declines and local extirpation. The data needed to identify specific abiotic and biotic factors limiting population persistence after reintroductions are lacking.

Identifying potential limiting factors can aid in attempts to establish and manage populations by prioritizing optimal conservation efforts. The environmental and biotic variables that influence plains topminnow populations have been postulated based on factors associated with the reduction of other endemic stream fishes (Dauwalter and Rahel 2008; Smith et al. 2014), topminnow morphologic characteristics (Rahel and Thel 2004), interactions with competitors and predators (Schumann et al. 2015*a*, Schumann et al. 2016), and observed behavior of wild individuals (Bestgen 2014). Great Plains native fish populations are at risk of declines due to alterations to physical habitat and invasion of introduced species caused by changes in water and land use practices, illegal introductions, and fish stocking programs (Fischer and Paukert 2008*b*, Smith et al. 2014). The changing landscape of Great Plains streams has resulted in reduced sinuosity, which is essential for the formation of preferred backwater pool habitat (Beschta and Platts 1986). Similarly, water impoundments, changes in water use practices, stream fragmentation, and hydro-morphologic stream alterations may have substantial impacts on native prairie fish assemblages (Wanner et al. 2011, Pasbrig et al. 2012, Smith et al. 2014). Biotic pressures have been found to control other fish species with predator control (Lundgren et al. 2014, Munter et al. 2019), as well as prey availability (Kaemingk et al. 2014). Introductions of sport fish and invasions of introduced western mosquitofish (*Gambusia affinis*) may also be decreasing plains topminnow populations by predating on both juveniles and adults (Schumann et al. 2015a). Compounding the challenge of identifying appropriate limiting factors is the reality that each of these proposed factors may work separately or in concert to decrease plains topminnow abundance.

Evaluating factors limiting species success prior to fish reintroductions is rarely done (Minckley 1995, Seddon et al. 2007, George et al. 2009). Because wild plains topminnow populations are considered at risk and the species occurs naturally in low abundances, this study utilizes experimentally reintroduced populations paralleled with adaptive stocking strategies to identify factors that influenced the abundance of plains topminnow at extirpated historic occurrence sites. Our objectives were to: (1) identify factors that influenced the success of reintroduced plains topminnow populations at 17 Nebraska stream sites, and (2) examine model weight averages to direct future management feasibility models.

STUDY AREA

Study sites were a continuation of Schumann et al. (2017), where 17 plains topminnow reintroduction locations (Figure 1) consisted of 14 separate streams or rivers so that all ecoregions in Nebraska were represented (Dauwalter and Rahel 2008). These sites historically contained plains topminnow but were currently considered relict populations since this species had not been sampled there for a minimum of 10 years. The length of each study site was 40X the mean wetted stream width, with a minimum 150 m and a maximum 300 m. Study sites received stockings of plains topminnow in 2010 (Schumann et al. 2017). Species presence was assessed in 2014 and sites where plains topminnow were not encountered received an additional stocking of 1,012 fish per habitat hectare (2,500 per acre) in 2014. A habitat hectare was defined by Schumann et al. (2017) as the wetted area with stream flows ≤ 0.407 m/s, which constituted pool, backwater and marginal bank areas. In total, nine sites received stockings and eight sites received no additional stockings.

METHODS

Fish assemblage

Fish community sampling utilized single-pass backpack electro-shocking with a Smithroot LR-24 backpack

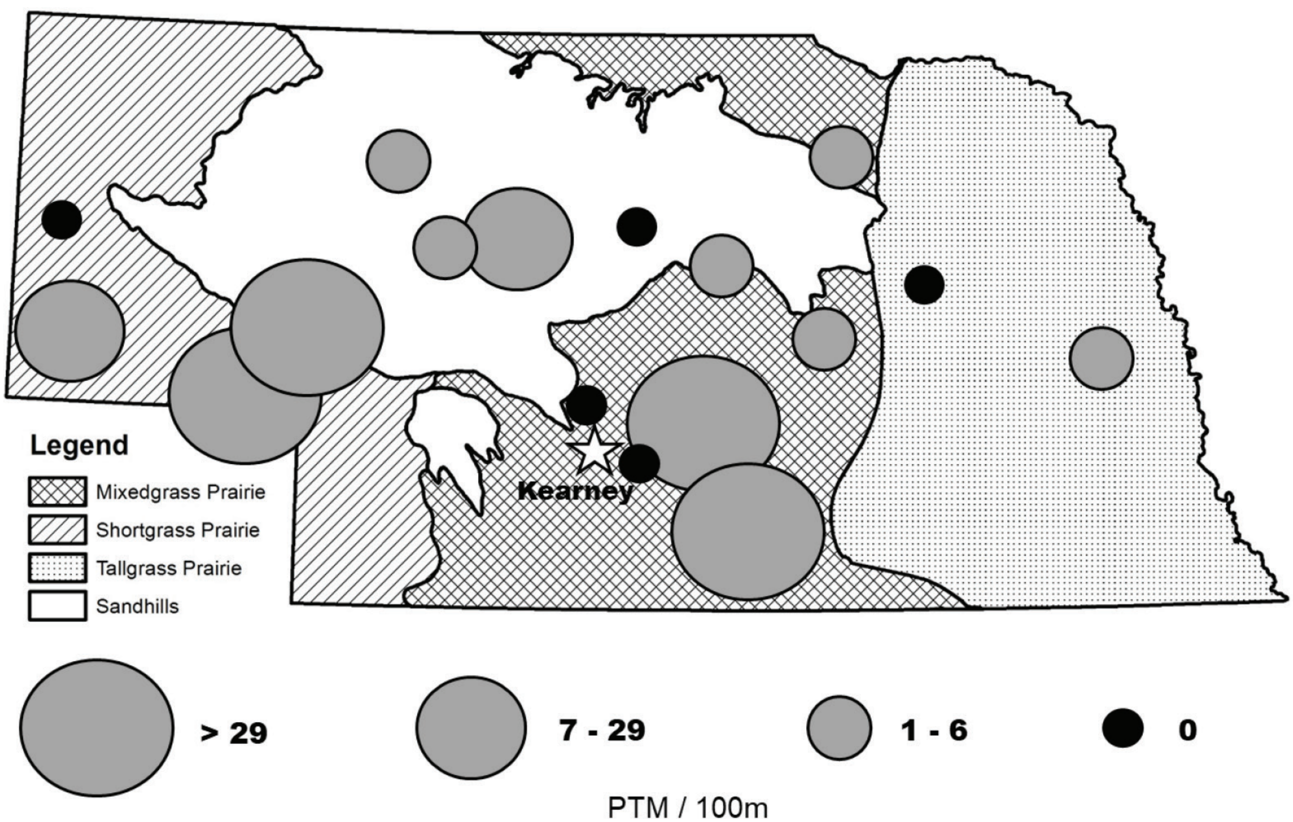

Figure 1. Plains topminnow (PTM) reintroduction sites across Nebraska ecoregions and individual site catch per unit effort (CPUE; number/100 m) from backpack electrofishing efforts post reintroduction efforts.

shocker, at optimized outputs for each site (Bertrand et al. 2006). Sampling sites were consistent with the previously established locations (Schumann et al. 2017). Fish collected were held in a bucket containing a portable aerator and water from the sample location. All captured fish were identified and enumerated before being released back into the stream. Sampling was conducted in 2015 between August and October as this timeframe was previously identified as having the highest seasonal capture efficiency of plains topminnow (Pasbrig et al. 2012). Relative abundance was indexed as catch per unit effort (fish/100 m of shocking) for all collected species.

Abiotic sampling

Abiotic data were collected in 2015 following the EPA Wadeable Streams and Rivers Rapid Biomass Standardized Sampling Protocol (Barbour et al. 1999), which included stream width and stream depth. Physical habitat sampling protocol followed EPA standards set by Kaufmann et al. (1999) and included slope, flow, temperature, and thalweg. Bank slopes and stream depths (m) were measured at five random locations within each stream reach. Bank slopes (degree angle) were measured from the current waters-edge at the time of visit. Total dissolved solids (TDS; mg/L) and water temperature (temp; °C) were measured prior to other data collection at the furthest downstream point of each study transect, using the HANNA combo HI98129 meter. Available backwater pool (BWP) habitat was determined based on stream flow regimes, where velocities ≤ 0.407 m/s were considered habitable by plains topminnow, as this is the average swimming velocity for the species (Prenosil et al. 2016). Hydrologic habitats encountered included trench pools, runs, lateral scour pools, backwater pools, dam pools, glides, and riffles. The transition between stream flows and aquatic habitat velocity were identified using a single reading with an OTT MF pro handheld flow meter at 60% of stream depth. Riffles were identified based on their range of flow; then counted and measured to the nearest cm^2 for the entire transect length of each study site to determine the available hydrologic habitat. Dominant substrate coarseness was visually estimated by the percentage composition of silt (<0.5mm), sand (0.5-2mm), fine gravel (2-16mm), coarse gravel (16-64mm), and cobble (64-240mm) at each study reach. Sinuosity was quantified as the ratio of thalweg length compared to straight line length in the described study site.

Variable selection and model development

We selected 10 variables thought to potentially limit plains topminnow from the published literature or in conjunction with Nebraska Game and Parks Commission fisheries staff with working knowledge of regional freshwater systems (Table 1). Variables included were characterized as either physicochemical, geomorphic, hydrologic, biotic, or physical habitat and were collected in sampling efforts conducted in August – October 2015. These included available macrohabitats (i.e., backwater pool, flow regime) predator fish relative abundance (pred), total dissolved solids (TDS), water temperature (temp), average stream depth (streamdepth), estimated dominant substrate, average bank slope, estimated percent of submerged vegetation (stream veg.), sinuosity (Sinu), and species richness (total count of species presence). Multiple linear regression models were used to quantify the relationship between each model and plains topminnow relative abundance using R-Studio version 0.99.491 (RStudio 2015). The relationship of selected variables with plains topminnow relative abundance was considered to construct 15 competing models using the 10 biotic and abiotic variables, based on the working understanding of life history characteristics and ecosystem requirements of this species (Table 2).

Fish species were divided into two categories: (1) predator (piscivorous) and (2) non-predator based on life history. Predatory fish that were represented by the presence of a single individual at multiple sites consisted of channel catfish (*Ictalurus punctatus*), western mosquitofish, creek chub (*Semotilus atromaculatus*), green sunfish, and largemouth bass. Recent studies suggest negative plains topminnow population impacts result from *Gambusia* spp. aggressive harassment towards adult and predation on juveniles (Haas 2005, Schumann et al. 2016) and that minimal diet overlap was observed (Thiessen et al. 2018). Therefore, western mosquitofish were included as a predator for model development. Non-predator fish that were represented by the presence of a single individual at multiple sites included gizzard shad (*Dorosoma cepedianum*), common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), brassy minnow (*Hybognathus hankinsoni*), emerald shiner (*Notropis atherinoides*), white sucker (*Catostomus commersonii*), plains killifish (*Fundulus zebrinus*), sand shiner (*Notropis stramineus*), bigmouth shiner (*Notropis dorsalis*), red shiner (*Cyprinella lutrensis*), longnose dace (*Rhinichthys cataractae*), orangethroat darter (*Etheostoma spectabile*), and brookside stickleback (*Culaea inconstans*).

Available habitat was defined by collected flow readings based on the published threshold for maintained swimming

Table 1. Variable codes and description included in AICc model development for candidate model analysis, with value range (min-max), mean value, and standard error for each variable to predict relative abundance of reintroduced plains topminnow populations at 17 reintroduction sites in Nebraska. The PTM code was the response variable in the models. Backwater pools (BWP) was defined as the percent wetted area with stream flows ≤ 0.407 m/s.

Code	Description	min-max	mean	SE
PTM	Plains topminnow /100m	0-243.6	27.1	15.2
pred	Predator fish /100m	0.7-243.6	60.6	20.9
speciesrich	Total species/100m	5.0-19.0	9.9	0.9
TDS	Total dissolved solids (PPM)	80.0-630.0	257.8	42.8
sinu	Sinuosity (thalwag)	10-16.6	12.2	0.5
temp	Avg. stream temperature (C°)	10.9-23.7	16.3	0.9
streamdepth	Stream depth (m)	0.18-3.16	0.6	0.2
bankslope	Avg. degree of bank angle	0.16-3.16	1.4	0.2
stream.veg	In-stream vegetation (%)	0-100	23.1	10
substrate	Dominant substrate (mm)	0.25-12	2.4	0.7
BWP	Available backwater pool habitat/100m (%)	0.42-100	22.8	8.3

Table 2. AIC_c candidate models and rank for best fit models predicting relative abundance of reintroduced plains topminnow populations in Nebraska, as determined by the Akaike's information criterion for small sample size AIC_c rankings. Δ_i is the change in AIC_c values between models and wi is the Akaike's weight. Individual model code parameters are located in the methods section.

Model	R^2	AIC_c	Δ_i	w_i
pred+temp+BWP+TDS	0.62	135.11	0.00	0.57
pred+sinu+BWP	0.49	138.41	3.30	0.11
pred+temp+sinu+BWP+stream.veg	0.59	138.70	3.59	0.09
bankslope+streamdepth+BWP	0.47	139.02	3.91	0.08
sinu+temp	0.39	139.33	4.22	0.07
temp+streamdepth+substrate+BWP+speciesrich	0.54	140.33	5.22	0.04
pred+speciesrich	0.26	142.65	7.54	0.01
substrate+bankslope	0.24	143.04	7.93	0.01
TDS+streamsdepth+substrate	0.28	144.21	9.10	0.01
sinu+bankslope+substrate	0.24	145.03	9.92	0.00
streamveg+speciesrich	0.06	146.56	11.45	0.00
TDS+speciesrich	0.02	147.29	12.18	0.00
TDS+bankslope+streamveg	0.13	147.31	12.20	0.00
sinu+speciesrich	0.00	147.70	12.58	0.00
sinu+streamdepth+streamveg.	0.07	148.42	13.31	0.00

speed of this species (Prenosil et al. 2016). Estimated dominant substrate was included as Schumann et al. (2015*b*) found this to be a predictor of plains topminnow presence at site locations. Total dissolved solids (TDS) was included as plains topminnow have been associated with clear headwater streams with low TDS (Rahel and Thel 2004). Average stream depth was included because plains topminnow have been associated with shallow backwater habitats, as deeper pools have the potential for holding predator fish (Rahel and Thel 2004, Schumann et al. 2015*b*). Plains topminnow rely on instream vegetation for egg deposition and gastropod feeding (Rahel and Thel 2004, Thiessen et al. 2018), therefore estimated percent of instream vegetation was included as an explanatory variable. Species richness was included due to it being a common predictor for endemic fish presence at stream sites (Poff et al. 1997).

A total of 15 competing models were developed by the assembled review team to reflect combinations of conditions that have previously been associated with Plains topminnow CPUE (Table 2). We used Akaike's Information Criterion for small sample sizes (i.e., AICc) to rank the competing models (Burnham and Anderson 2002). Model averaging was used across all candidate models with associated parameter estimate standard error by calculating,

$$\tilde{\bar{\beta}} = \sum_{i=1}^{R} w_i \hat{\beta}_i$$

$$\widehat{var}\left(\tilde{\bar{\beta}}\right) = \sum w_i \left[\widehat{var}\left(\tilde{\bar{\beta}}\right) + \left(\beta_i - \tilde{\bar{\beta}}\right)^2\right]$$

where, $\tilde{\bar{\beta}}$ is the parameter estimate, w_i is the perspective model weight, and $\hat{\beta}_i$ is the regression estimate for model *i* (Burnham and Anderson 2002). We estimated the relative importance of each individual predictor variable by summing the weights of all models containing each variable (Σw_i; Burnham and Anderson 2002, 2004). Models with zero weights were omitted (Burnham and Anderson 2002, 2004). Predictor variables with the largest total weight were considered to have the greatest relative importance for explaining the dependent variable, topminnow abundance (Burnham and Anderson 2004). Ranking factors in terms of relative importance using this approach rather than making inferences from best model fit alone reduces variable selection bias and increases precision, which can be useful when multiple candidate models exhibit support of the dependent variable (Burnham and Anderson 2002, Burnham and Anderson 2004).

RESULTS

Plains topminnow relative abundance ranged from 0.0 – 243.6/100 m at the 17 sample sites (Figure 1). Abiotic conditions were variable as an eight-fold difference was noted between sites for total dissolved solids readings and a two-fold difference in recorded water temperature (Table 1). Available backwater pool habitat ranged from <1-100%, but other habitat variables like sinuosity were more consistent across sites (Table 1).

The top performing model included predator CPUE, stream temperature, backwater pool availability, and total dissolved solids (Table 2). Backwater pool availability appeared in five of the top six models, while predator CPUE was in the top three models (Table 2). Sinuosity was not included in the top model but did appear in three of the top five models (Table 2). Variable weight summation determined limited backwater pool availability ($\Sigma w_i = 0.89$), increased predator fish abundance ($\Sigma w_i = 0.78$), and colder stream temperatures ($\Sigma w_i = 0.77$) to be the three variables with the greatest relative importance limiting plains topminnow relative abundances (Table 3). Model averaging estimates suggest low plains topminnow CPUE was best predicted by relatively high predator fish CPUE and total dissolved solids; while high plains topminnow CPUE was best predicted by increased backwater pool availability and stream temperatures (Table 3).

DISCUSSION

The anthropogenic degradation of Great Plains streams has been observed over the last century (Dodds et al. 2004) and has impacted native fishes such as the plains topminnow.

The factors suggested by this study to be limiting plains topminnow relative abundance are commonly associated with degraded prairie streams, while factors suggested to increase relative abundance are descriptive features in minimally disturbed Great Plains streams (Falke and Gido 2006, Fischer and Paukert 2008*a*). This study determined that relative abundance of reintroduced plains topminnow populations decreased with increased predator fish abundances, turbidity, and bank slope. Increased plains

Table 3. Final model averaging estimates for variables influencing reintroduced Plains topminnow abundance at 17 release sites in Nebraska, with standard error (SE), and AIC relative importance (Σw_i).

Predictor variables	Parameter estimate	SE	Σw_i
Backwater pools	0.52	0.64	0.89
Predator fish	-0.04	0.19	0.78
Stream temperature	1.63	0.38	0.77
Turbidity	-0.01	0.04	0.57
Sinuosity	-0.23	0.52	0.28
Average stream depth	-0.84	0.58	0.13
% Submerged vegetation	-0.02	0.03	0.10
Average bank slope	0.01	0.09	0.10
Dominant substrate	-0.51	0.90	0.06
Species richness	-0.05	0.26	0.06

topminnow relative abundance was higher when sites had increased backwater pool habitat, water temperatures, stream sinuosity, and submerged vegetation. Large scale alterations of Great Plains waterways have decreased shallow backwater stream habitat availability, which has shifted fish assemblages favoring lentic sport fish, introduced generalists, and decreased native fish populations (Smith et al. 2014). Collectively, this study suggests minimally disturbed stream sections may provide increased potential for higher abundances of reestablished plains topminnow populations, while the factors associated with degraded stream systems potentially limit the size of reintroduced populations. A lack in effort to recover the plains topminnow will inevitably increase considerations for Federal protection designation. However, recovery efforts have been initiated in Nebraska by reintroducing and supplementing historic locations and river drainages (Koupal et al. 2015, Schumann et al. 2017). These efforts are key to stabilizing plains topminnow populations, but also represent an avenue for better understanding what factors influence the persistence of these populations, which was the focus of this work.

MANAGEMENT IMPLICATIONS

The results of the current study suggest limited backwater pool availability, relative predator fish abundance, and stream temperature at reintroduction sites influence plains topminnow abundance post stocking. Because of our findings we suggest conservation efforts to recover plains topminnow populations should focus on these parameters by looking to maintain the natural integrity of Great Plains streams with consideration of variables like stream sinuosity. Our results also indicate abiotic conditions such as geomorphology, hydrology, and physical habitat loss limit reintroduced plains topminnow populations. Future reintroduction efforts of plains topminnow should be completed at historically inhabited sites where ample warm, backwater habitat persists with low turbidity and low predator abundance. Although the findings of this assessment resulted from reintroduced populations, the short life span of this species means that the specimens collected had not been cultured and consequently represent naturally recruited populations. Therefore, we believe the defined limitations identified in this study also persist for wild populations.

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NOTES

RECENT OBSERVATIONS OF WATER SHREWS IN NORTHEASTERN SOUTH DAKOTA—North American water shrews in the genus *Sorex* are a complex of at least five species, three of which were recognized historically, *Sorex alasksans*, *S. bendirii*, and *S. palustris* (Hall 1981). Within what was previously considered the single, widespread northern species, *S. palustris*, two additional species are now recognized, *S. albibarbis* in the eastern US and Canada and *S. navigator* in the western United States and Canada (Hope et al. 2014; Nagorsen et al. 2017; Woodman 2018). The American water shrew (*Sorexpalustris*) originally was documented in South Dakota by three females, two werecollected 1876 and one in 1878 by Charles E. McChesney on the Fort Sisseton Reservation, which is in present-day Marshall County. Those specimens represented the southwestern most records for the speciesand have remained the only specimens known from South Dakota. All three specimens are in collectionsatthe Smithsonian Institution, Washington, D.C. (USNM 18428, 59600, and 59608).

Over and Churchill (1941) described water shrews as being common along rivers and around lakes innortheastern South Dakota; however, those researchers provided no information on observations or collections of the species. Higgins et al. (2000) noted the historical records from Fort Sisseton as the only known occurrences in South Dakota. Jones et al. (1983) reported that in the Northern Great Plains, the water shrew only is known from Fort Sisseton. In Minnesota, Hazard (1982) plotted the species as occurringonly in the northern third of the state, and Timm (1975)discovered the species to be locally abundant in northeastern Minnesota. Wilson and Ruff (1999) erroneously reported the USNM specimens from Fort Sisseton Reservation as having been collected in Nebraska.

We recently collected two specimens of the American water shrew near Pickerel Lake in northeastern Day County, South Dakota. On 24 June 2014, a female was collected adjacent to a perennial tributary of Pickerel Lake along 128th Street(45.529°N, 97.277°W; WGS 84).On 15 June 2016, a malewas obtainedadjacent to the lake's outlet along 446th Avenue(45.503°N, 97.288°W; WGS 84). Pickerel Lake is a natural spring-fed lake. Common reed grass (*Phragmites*) and cattails (*Typha*) are the dominant plants occurring along the lake's perennial tributaries where the two specimens were recovered. Both individuals were deceased at the time they were discovered, and we assume that the shrewswere killed by a predator and discarded. The Day County site is about 25 km south of the Fort Sisseton Reservation, and now represents the southwestern most records for the species in the region. Both specimens were deposited in the mammal collection at the University of Kansas (KU 171678, F; 171679, M).

Selected measurements for the female(KU 171678) are:total length, 140 mm; length of tail, 59 mm; length of hind foot, 18 mm; length of ear, 6 mm; condylobasal length, 21.8 mm; cranial breadth, 10.5 mm; maxillarybreadth, 6.2 mm. The male (KU 171679) had testes that measured 5× 3 mm. Further measurements of the male were not made due to the condition of the specimen. These measurements are comparable to those recorded by Timm (1975) for *S. palustris* from northern Minnesota, albeit the condylobasal length is somewhat larger than specimens from Minnesota.

Sorex palustris in South Dakota might represent anisolated population. Seabloom (2011) lists *S. palustris* as potentially occurring in North Dakota. Sweitzer (2001) did not detect *S. palustris* in a vertebrate survey of the Sheyenne Grasslands of North Dakota located 70 miles north of Pickerel Lake. In Minnesota, Rubbelke and Saupe (1984) considered northcentral and northeast regions as the only known range for water shrews in the state. *Sorex palustris*, however, may be more widespread than current data and these publications suggest because the species is difficult to detect. One of the authors (DS) and several colleagues failed to capture water shrews in northeastern South Dakota in past surveys (Skadsen, unpublished data).

These two recent observations of *S. palustris* from South Dakota were collected during a tributary water quality study of Pickerel Lake funded by a United States Environmental Protection Agency 319 Clean Water Grant administered by the South Dakota Department of Environment and Natural Resources. The South Dakota Natural Heritage Database, Department of Game, Fish and Parks provided additional information on the specimens obtained at the Fort Sisseton Reservation. Maria Eifler's efforts at the University of Kansas Natural History Museum are most appreciated.–*Dennis Skadsen, Northeast Glacial Lakes Day Conservation District, Webster, SD, USA 57274 (DS); Robert M. Timm, Department of Ecology and Evolutionary Biology and Natural History Museum, University of Kansas, Lawrence, KS, USA 66045 (RMT).*

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BOOK REVIEWS

SKY DANCE OF THE WOODCOCK: THE HABITS AND HABITATS OF A STRANGE LITTLE BIRD.
Greg Hoch. 2019. University of Iowa Press, Iowa City, Iowa, USA. 174 pages. $30.00 (paper). ISBN: 978-1-60938-627-6.

American Woodcock (*Scolopax minor*) have enthralled conservationists (including Aldo Leopold), bird watchers, wildlife enthusiasts, hunters, and others interested in the natural world for centuries. No doubt, woodcock also have enthralled humans in North America for millennia prior to written descriptions of the woodcock's courtship displays, habitat preferences, and curious behavior and anatomy. As perhaps the most extensively studied species of shorebird in the world, there is a rich and extensive literature, both scientific and popular, focused on woodcock ecology, behavior, and hunting. To that extensive body of literature, *Sky Dance of the Woodcock* provides an updated summary of their natural history, habitat relations, and conservation.

Sky Dance of the Woodcock takes its title from the courtship display of male woodcock, which consists of an elaborate aerial flight incorporating sound produced both vocally and mechanically via highly modified flight feathers. The aerial displays are accompanied by similarly unusual behavior on the ground, including a distinctive 'peent' call. This courtship display happens across much of eastern North America each spring, and Hoch uses this wonder to capture the imagination of the readers of his text. Hoch begins the book with an overview of some of the mystery and fascination surrounding woodcock and builds from that opening to describe woodcock anatomy, natural history, and behavior, before describing their courtship display in greater detail. From there, Hoch describes woodcock-habitat relations, provides a historical overview of woodcock hunting, identifies current threats to woodcock populations, summarizes past and recent woodcock research, and finally, presents an updated overview of woodcock conservation and habitat management. Throughout, there is sometimes surprising information about things as simple as what woodcock eat, to more complex assessment of how woodcock use landscapes and migrate to and from spring and summer breeding areas.

In some respects, *Sky Dance of the Woodcock* is an update of Sheldon's (1967) classic *Book of the American Woodcock* that incorporates considerable new information about woodcock ecology and conservation generated since that book was published. As with Sheldon's (1967) book, *Sky Dance of the Woodcock* is geared toward a broad audience and is not directed solely at a scientific audience. As such, it is a mix of old and new science, past and current fascination with woodcock, and suggestions for managing woodcock habitat. It is heavily annotated with quotations from both the scientific and popular literature on woodcock and, as a result, provides an extensive reference to pertinent scientific and popular literature. The book includes 19 gray-scale figures that include photographs of woodcock nests, chicks, and feathers and graphs illustrating cover-type distribution, trends in American Woodcock Singing-Ground Survey data, and woodcock harvest estimates. The book clearly conveys Hoch's fascination and enchantment with woodcock, and he does his best to impart his enthusiasm throughout.

Overall, *Sky Dance of the Woodcock* is a comprehensive overview of woodcock ecology, conservation, and summary of the fascination of woodcock from both a popular and scientific perspective. It is a quick read, although the extensive quotations are sometimes distracting, and I sometimes found the writing to transition abruptly. I also found Hoch's terminology around woodcock habitat and land-cover types continued the confusion described by Hall et al. (1997), and I think that Hoch missed an opportunity to help clarify the concept of habitat as it relates to woodcock, especially to a general audience. From a scientific and ecological perspective, the term "habitat" refers to the biotic and abiotic factors that influence occupancy by a particular species (woodcock, in this instance), and does not refer to land cover or the vegetation community that occurs in a particular place. In that context, it makes sense to discuss woodcock breeding or migration habitat and early successional forest cover types, but not early successional forest "habitat". Although a minor issue, there is also an error related to determining woodcock age based on wing characteristics, i.e., describing the pattern of mottling on feathers in adult woodcock as symmetric on both sides of the rachis when it is asymmetric. However, these considerations do not detract significantly from the book.

As with any book that attempts to summarize existing knowledge about a particular topic, the summary is often outdated before it is published. In the case of *Sky Dance of the Woodcock*, Hoch was unable to incorporate information from the most recent 11th American Woodcock Symposium, the proceedings of which are currently published online (Krementz et al. 2019). Having access to the information contained in those symposium proceedings would have provided the opportunity to incorporate results of some of the most recent woodcock research, but that information can be freely accessed electronically by readers interested in finding out more about woodcock and their habits and habitats. What will be missing is Hoch's opportunity to incorporate that information into the larger picture that he paints.

This book will undoubtedly appeal to woodcock enthusiasts of a variety to stripes. Woodcock hunters and bird watchers alike will learn something about woodcock-habitat relations, behavior, and conservation. Professional biologists and researchers will benefit from Hoch's synthesis of a wide range of information about woodcock, and landowners and managers can use some of the concepts in this book to inform their decisions about how to manage lands under their control. Along the way, everyone who reads *Sky Dance of the Woodcock* is likely to come away with an enhanced appreciation of this captivating bird.—*David E. Andersen, Leader, U.S. Geological Survey Minnesota Cooperative Fish and Wildlife Research Unit, 1980 Folwell Avenue, St. Paul, Minnesota 55108, USA.*

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BIRDS OF PREY OF THE EAST: A FIELD GUIDE.
Brian K. Wheeler. 2018. Princeton University Press, Princeton, New Jersey, USA. 296 pages. $27.95 (paper). ISBN: 978-0-691-11706-5.

Brian Wheeler's new field guide, *Birds of Prey of the East*, is a well-researched, comprehensive field guide to birds of prey found in eastern Canada and United States. This 13-year labor of love reflects a life spent studying the nuances of North American birds of prey, as well as partnerships with fellow enthusiasts who provided detailed range maps and other valuable inputs. *Birds of Prey of the East* features 72 color plates of 27 species, including 14 plates for the Red-tailed Hawk (*Buteo jamaicensis*), which can be one of the most challenging species to identify in North America. This compact, sturdy guide can be dropped into a backpack or kept in a vehicle's glove box and can be used by beginner to advanced birders.

The color plates are a comprehensive visual guide. For most species, there are side-by-side comparisons of perched birds, flying birds (top-side and bottom views), tails, and even individual feathers types. High plumage variation within raptor species emphasizes the importance of providing readers with the most common plumage and then a few less-common variations. Wheeler gives extra attention to tails because the tail is often the last view of a flying raptor that a birder observes, and tails often can be hugely helpful for raptor identification. Many raptors can be aged by plumage and molt variations, which also are described in the plates and text.

The range maps are a valuable asset to this field guide. Wheeler partnered with John M. Economidy, who researched and created range maps that show breeding, year-round, and wintering ranges. These range maps include incidental sightings or uncommon breeding records, which can be helpful to birders when a bird is encountered outside of its expected range. Also, because this field guide focuses on eastern North America, the range maps are more detailed than the larger, more generalized range maps in field guides that cover the entire continent.

Each species account is accompanied by a color plate and text that describes plumage and basic information about habitat, prey, and other tidbits. The plumage descriptions correspond to the plates, helpfully pointing out unique features of a species that could be hard to articulate. Photos of representative habitat are included for some species, which can be helpful for birders who are unfamiliar with a species or are birding outside of their normal neighborhood. The author focused on identification instead of including general natural history information for each species, which can add a lot of joy to birding by learning about the species you have just identified or perhaps have seen for the first time. The description of Red-tailed Hawks is jam-packed and comprehensively covers their variations. Some descriptions can be quite dense and may be useful only for the most enthusiastic birders.

I recommend packing this field guide for a day of birding or stocking it on a bookshelf at a hawk migration site. *Birds of Prey of the East* would be complementary to Jerry Liguori's (2005, 2011) field guides that help identify birds of prey in the field at a distance. The color plates in *Birds of Prey of the East* are of great value; however, the plates are missing some niceties, such as side-by-side comparisons of tricky species such as Sharp-shinned (*Accipiter striatus*) and Cooper's (*Accipiter cooperii*) hawks. *Birds of Prey of the East* is probably best for the intermediate to advanced birders because its comprehensiveness, which is excellent, may be overwhelming for beginners that are looking for basic identification traits. The real mettle behind a field guide that focuses on birds of prey is the section dedicated to the variability in Red-tailed Hawk plumages. They are complicated beasts, and Wheeler uses highly researched visuals and text to illustrate the nuances of Red-tailed Hawk plumages. This is another gem of a field guide that will hopefully see some sun and dirt in the field.—*Janet W. Ng, Department of Biological Sciences, University of Alberta, 11455 Saskatchewan Drive, Edmonton, Alberta T6G 2E9, Canada.*

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GREAT PLAINS BIRDS.

Larkin Powell. 2019. University of Nebraska Press, Lincoln, Nebraska, USA. 224 pages. $16.95 (paper). ISBN: 978-1-4962-0418-9.

Biologists who live in the Great Plains of North America know well the general aspersion cast toward our regional home by those unfamiliar with the region and its natural treasures. Larkin Powell alludes to this all-too-common aspersion and diplomatically dispels it in his ornithological showcase of the Great Plains, simply titled *Great Plains Birds.* The book is a nice, quick read and a well-composed profile of the region's avian biogeographical history, its disruptions, conservation remedies, examples of basic bird biology, and tips on how to enjoy the bird life on display in this dynamic region.

Having been an ornithologist and birder in the greater Great Plains region for many years, upon receiving the book, I was mildly interested in the title, thinking of what the work might offer to birders from afar visiting the Great Plains, and perhaps other outdoor enthusiasts. I was pleased to find that Powell does a fine job of catching and maintaining interest (even for my old bird brain) with his light-hearted prose and personal reflections on becoming enchanted with birds of the midcontinent. I expect his approach to be accessible by youngsters (importantly!), layman naturalists, and bird fanciers among the general public, and the book should maintain the interest of diehard birders. For the few of us academic and conservation professionals who digest bird science, it was nice to see profiles of research by fellow ornithologists in the region presented in a popular literature-style format outside of peer-reviewed scientific journals.

While highlighting the many blights of modern civilization on the natural world as a result of our expanding human population and its agricultural industry, Powell is pragmatic in putting the lives of agricultural producers in the broader context of surviving in the dynamic environment of the Great Plains. Incentives are at play that drive human decisions. Those incentives are economically driven as well as shaped by our conservation ethic, which we all share at some basic level. Regretful decisions by society are made and can be undone, if only in part, by restoring habitat and its wildlife dependents. Powell reminds us that landowners are key in this decision-making process.

In addition to modern human connections to the landscape and its birds, Powell reaches farther back to Native American relationships with Great Plains avifauna. Aboriginal connections with large mammals (principally American Bison [*Bison bison*]) dominate our perspectives of times predating modern industrial settlement in the Great Plains. However, there also remains an oral history of Native American fascination with birds—a fascination common to all humankind. Many delightful stories, or legends, associated with this history are shared with the reader, mostly through quoted passages from the region's native inhabitants.

Perhaps most satisfying for me as an ornithology professor is that Powell's book parallels much of the ornithology course that I—and others, via standard ornithology texts—teach using our Great Plains avifauna as exemplary subjects. *Great Plains Birds* covers aspects of bird evolution, biogeographic history (including deep geological history that affected it), sexual selection of mating displays, migration ecology, and a tour of avian taxonomic groups. I am strongly considering this text as required reading for my future ornithology courses so the students can relate what we generally teach about birds to the interesting critters flying around in their own geographical neighborhood.

Potential criticisms are few. One could disparage the anthropomorphisms that Powell uses in describing bird behaviors (e.g., assumptions about the thoughts of birds), but I, for one, find these sorts of illustrations useful metaphors for pondering why birds might be reacting as they do and why these behaviors—and avian capacity for learning—have been inherited and evolutionarily preserved. Other than that, a few typos were distracting (of which we all are guilty), but those errors ultimately lie with the publisher.

Great Plains Birds ends with a guide for birders and nature enthusiasts to some birding hotspots across the Great Plains, including bird communities of grasslands, wetlands, and woodlands. Powell also reminds us of birding ethics—it is important that all birders understand the ethics of birding and practice these principles in the field! I expect this book will be of interest to students, birders, and anyone who is fascinated by birds (which should include just about everyone!), including those of us residing in 'flyover country' and visitors alike.—*William E. Jensen, Professor, Department of Biological Sciences, Emporia State University, Box 4050, 1 Kellogg Circle, Emporia, Kansas 66801-5415, USA.*

GRASSLANDS AND CLIMATE CHANGE.
Edited by David J. Gibson and Jonathan A. Newman. 2019. Cambridge University Press, Cambridge, United Kingdom. 348 pages. $89.99 (hardcover), $44.99 (paper), $36.00 (digital). ISBN: 978-1107195264 (hardcover), 978-1316646779 (paper).

The last decade has seen an explosion of information about climate change, some of which is contradictory, much of which is confusing, and the entirety of which is too much for the typical biologist or scientist to assemble and comprehend. This is why reviews such as *Grasslands and Climate Change*, edited by David Gibson and Jonathan Newman, are so valuable.

To produce this review of climate change issues and influences relative to grasslands, Gibson and Newman recruited 30 scientists—predominantly from Europe and North America—who wrote 19 chapters dealing with various aspects of grasslands and climate change. The chapters are grouped into a general introduction and three subsequent sections, each of which is prefaced with a short introduction.

The first chapter of the general introduction provides an overview of grasslands, their variety and importance, and the increasing pressures they are experiencing from ever-growing human populations. This is followed by a methodology chapter, which evaluated the focus, timing, treatments, methodology, response(s), ecological complexity, and experimental design of 841 studies of grasslands and climate change. The final chapter of the general introduction covers remote sensing of change in grasslands, with an excellent review of the mechanisms and methods of evaluating landscapes using satellite imagery and other remotely sensed data. These three introductory chapters set the tone for the book by being well organized and easy to understand, with strong emphasis on how study design, spatial scale, temporal scale, replication (or lack thereof), methodology, and analytical techniques affect inferences that can be made from research. Throughout the book there is repeated recognition of information gaps and the need to conduct research that is well designed and answers specific, targeted questions.

The remaining sections (Part I, *Grassland dynamics and climate change*; Part II, *Species traits, functional groups, and evolutionary change*; and Part III, *Dealing with climate change effects*) each contain five or six chapters on topics pertinent to the section, ranging from projected climate change and global distribution of grasslands to climate change effects on grassland ecosystem services to restoring grassland in the context of climate change. One of the chapters (*Projected climate change and the global distribution of grasslands*) contains a brief overview of various climate projection and vegetation distribution modeling techniques, which provides useful context for the book and for understanding climate change projections and research in general. With minor exceptions, the chapters were well organized, thorough, and easily readable. Credit must be given to the editors and the authors for working to ensure a review that is consistent, concise, and readable but also informative.

Grasslands and Climate Change is written for a global audience, with examples and case studies from around the world. The chapters are generally very process oriented, with emphasis on plant physiology, communities, and management, as well as the economic and social values of grasslands. As a wildlife biologist who works in a system where grassland conservation is often dependent on the wildlife value that grasslands provide, I would have appreciated a chapter on grassland wildlife species, which are declining precipitously as grasslands are being lost and degraded.

Grasslands and Climate Change makes good use of figures, particularly flowcharts and diagrams that illustrate concepts from the chapters. My single biggest complaint about the book is that the publisher used gray-scale versions of color figures in the chapters, including figures where discriminating among colors is necessary for comprehension, but impossible in gray-scale. This necessitates flipping to the central section of the book where color figures are provided, but, inexplicably, several of the figures are printed out of sequence, which makes finding the appropriate figure cumbersome.

The book ends with a chapter entitled *Grasslands in the Anthropocene: research and conservation needs*, written by the editors. Research gaps are not only identified, but categorized as general experimental gaps, specific experimental gaps, modelling research gaps, or management research gaps, with numerous, specific topics identified in each category. Similarly, uncertainties related to climate change projections and ecological responses are identified, along with specific sources of uncertainty and suggestions for addressing them.

Grasslands and Climate Change has a strong academic and research focus with relatively little specific information that can directly be applied by conservationists and managers. Nevertheless, the book provides useful background information along with context for conservation and policy making and will be an excellent reference for people interested in how climate change might affect grasslands and grassland management, whether in the Great Plains or across the globe.—*Neal D. Niemuth, Conservation Scientist, U.S. Fish and Wildlife Service, Habitat and Population Evaluation Team, 3425 Miriam Avenue, Bismarck, North Dakota 58501, USA.* *The findings and conclusions in this article are those of the author and do not necessarily represent the views of the U.S. Fish and Wildlife Service.*

The Great Plains Natural Science Society

The Great Plains Natural Science Society, formerly the North Dakota Natural Science Society, was founded in 1967 and seeks to promote interest in and understanding of natural history in the Great Plains, to encourage the conservation of natural resources, and to provide communication among individuals, institutions, and organizations of like interests. The GPNSS actively promotes the study of natural history of the Great Plains region, including geology, plants, birds, mammals, fish, insects, and other forms of life. Together with local, state, and national conservation organizations, the GPNSS fosters natural resource conservation and preservation of outstanding natural areas. The GPNSS publishes *The Prairie Naturalist*, a widely read, peer-reviewed journal which deals with the natural history and environment of the Great Plains region.

The GPNSS is currently composed of a diverse membership, many of whom are professional scientist. Society members have strong interests in sustainable management of Great Plains natural resources and their habitats. Natural history and ecology of the Great Plains is the primary focus and interest of the GPNSS, thus, the primary interests and goals of the Society seeks to promote increased scientific knowledge of the interactions of all Great Plains organisms with their natural environments, enhance professional stewardship of Great Plains natural resources and their habitats, and encourage use of applied research for informing Great Plains natural resource policy decisions.

The GPNSS hosts annual meetings and serves host to symposiums covering a broad spectrum of topics. Located jointly within the Department of Biological Sciences at Western Illinois University and 410 Sunset Lane in Brookings, South Dakota, the GPNSS takes great pride in working with students, staff, and faculty to foster a greater understanding of the natural history and ecology of Northern Great Plains organisms and their biota.

First published in 1969 by the University of North Dakota, *The Prairie Naturalist* has been published by Minuteman Press since 2013 and fills an important role as the avenue of communication of research on the North American grasslands and their biota. Research topics include articles investigating Great Plains community and landscape ecologies, species-specific population dynamics, mammalogy, ornithology, invertebrate zoology, herpetology, ichthyology, botany, animal behavior, infectious diseases, and biostatistics. This journal offers timely technical information for researchers, educators, students, and the interested public. Published quarterly, *The Prairie Naturalist* reaches subscribers throughout the United States and Canada, as well as libraries in Europe and Asia. A portion of each volume is devoted to shorter and less comprehensive communications (notes) and book reviews. Manuscripts containing original material not submitted elsewhere are considered for publication; all are reviewed by specialists in relevant fields.

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